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The Diffusion Of Minor Technical Productivity And Quality Of Working Life Improvements Within A Firm With Multiple Operating Units

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THE DIFFUSION OF MINOR TECHNICAL PRODUCTIVITY AND QUALITY OF WORKING LIFE IMPROVEMENTS WITHIN A FIRM WITH MULTIPLE OPERATING UNITS

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ABSTRACT

The productivity and quality of working life of operations across a firm with multiple operating units can be improved by the diffusion of minor innovations within the firm. The benefits to operating performance which result from a continuous stream of small, incremental innovations over time are well documented. However, the extent that individual minor innovations, called Minor Technical Improvements (MTIs) in this thesis, are actually used or could be potentially used throughout the firm, is not well documented. This thesis addresses four basic questions in order to explore the opportunities and problems associated with the diffusion of minor innovations in firms with multiple operating units. They are:

1) To what extent do MTIs actually diffuse?

2) What is the potential for further diffusion of MTIs?

3) What are some of the influences on the diffusion of MTIs?

4) What are the implications of MTI diffusion for operating improvement?

The field site for the research was 13 operating units of Canada's largest domestic mining company. A total of 73 MTIs were documented on video tape and in writing, taken from 13 mines and mills.

The results from the research indicate that MTIs actually diffuse to other parts of the firm. There is a significant potential for MTIs to diffuse even further. Operating units within the research site improved productivity and quality of work life by innovating MTIs within the confines of their own operations. Some of these benefits were transferred to other operating units by the diffusion of MTIs. Even greater benefits could be realized across the research site by further diffusion. The research site may have incurred significant opportunity costs by not pursuing this potential in the past. The research results emphasize the importance of effective communication among all parts of the firm, as an influence on the extent of MTI diffusion.

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I dedicate this thesis to my father, Kenneth R. Johnston.

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CHAPTER 1

INTRODUCTION

It is possible to improve operations in two ways. The first is to spend a lot of money and buy new technology to improve efficiency, reduce operating costs and/or increase capacity. The second is to spend very little money and try to get the most out of existing people, facilities, systems and resources. The first way has become less attractive in industries such as mining as declining operating margins fail to support large capital expenditures. The second way has become more attractive as firms have realized that operating performance can be improved by using the resources already in place more effectively. This way depends to a large extent on employees taking smaller, often very simple ideas and turning them into working innovations. These small process innovations are called Minor Technical Improvements (MTIs) in this dissertation. Occurring at various locations throughout a firm, MTIs incrementally improve operations.

The impact of continuous improvement on operations from the accumulation of MTIs over time is observable in the more productive use of resources and a better quality of working life. Some MTIs reduce the amount of labour needed to perform tasks; others conserve or more effectively utilize materials and machinery. Production bottlenecks and quality problems which restrict output are removed. Some MTIs make people's working life a safer, healthier and possibly a more fulfilling experience by removing irritants, hazards and restrictions associated with doing the job. Many MTIs from numerous employees, offering a range of benefits, can add up to large operating improvements over time.

Operating improvements resulting from MTI innovation in one part of the firm may also be of use to other parts of that same firm. A firm with a number of similar production facilities could increase the benefits of an MTI by diffusing MTIs from one facility to another. Of course, diffusion could occur only after a receptive potential user is made aware of the MTI by the innovator or some other agent. If potentially useful MTIs diffuse throughout the firm, then there may be opportunities to avoid redundant activities aimed at satisfying common needs for innovation shared by a number of facilities. These may be physically separate facilities or separate departments in the same facility. Managers of these facilities and their superiors, such as the vice president of production, who recognize that some minor technical improvements can be passed between parts of the firm, have the opportunity to utilize a corporate-wide resource of employee innovativeness and experience.

Continuous Innovation and Operating Improvement

Some industries in Canada in the 1980's have been squeezed between increasing operating costs and unrelenting competitive pressure to decrease product prices. The response by some firms has been to improve productivity by more efficiently transforming inputs into outputs. At the same time, government regulation and the expectations of employees demand attention to a continuously improving Quality of Work Life (QWL). This includes safer and healthier work conditions and greater job satisfaction. Continuous operating improvement is therefore a response to urgent and ever present needs for operating improvement, as well as a desire to increase shareholders' earnings.

Major innovations such as new production processes are relatively infrequent events in most firms' histories. Time between successive major innovations is usually measured in years. However, not all innovations are major innovations affecting a large portion of a firm's operations and employees. And not all require large amounts of time and money to implement. Minor innovations, such as modifications to existing production processes, occur frequently. Time between successive minor innovations may be days. Minor innovations often do not affect a large portion of a firm's employees, nor are they difficult or costly to implement. Innovation may occur in isolation, unnoticed by other parts of the firm or top management. The benefits of such innovation therefore also occur in isolation, unreplicated by other potential users in the firm.

The effect of minor innovation on improving operations has been reasonably well documented. Over time, some firms and industries have accumulated economic benefits from a continuous stream of minor innovations which have surpassed the benefits of major innovations over the same period. Also well documented have been the contributions of tradesmen, labourers, and supervisors as well as the corporate research and development centers and the engineering departments as sources of minor innovation. Other research into QWL programs, employee involvement groups and suggestion plans has recorded the innovativeness of workers in suggesting and implementing QWL-related improvements to operations.

The minor innovations documented in this dissertation incrementally changed the operating process technology. As a result, productivity and/or the quality of working life improved in these operations. Some of these innovations involved the adoption of new equipment from suppliers and organizations outside the firm. Other innovations modified existing equipment and techniques. Some innovations were inventions by employees.

The Diffusion of Minor Innovations Within Firms

The potential for improvement of a firm's operations by a minor innovation has not been fully realized until it is in use by all parts of the firm which can use it. Unfortunately, minor innovations are not instantaneously diffused within a firm to all potential users. Over time, some minor innovations may diffuse beyond the local setting in the department or facility where they were first used, to the rest of the firm. More often than not, innovations are used exclusively in only one part of the firm. The benefits of MTI diffusion therefore go unrealized.

The literature on the diffusion of innovation is not complete regarding the actual and potential diffusion of minor innovations and their impact on improving operations within firms. Much of the research has concentrated on major innovations diffusing among firms, industries or economies. The consensus from this literature is that innovation in general is not easily transferable from location to location. Not all innovations are adaptable. Not all innovations are considered worth the promotion by the innovators and the search by the potential user. Some people will not use technology that they themselves have not innovated. Alternatively, they may prefer to develop innovations exclusively in-house. All these reasons help explain why major innovations may be difficult to diffuse, but not whether minor innovations are capable in some circumstances of diffusing.

The diffusion of minor innovation within firms, or intra-firm diffusion as it sometimes called, has often been ignored or considered trivial in the literature. Conventional wisdom seems to be that minor innovations tend not to diffuse. The reasoning is that minor innovations do not often affect the whole firm; therefore, only a small number of people will be involved or affected to such a degree that they will be aware of the minor innovation. This does not negate the potential for the diffusion of MTIs. Some large firms have a number of divisions, subsidiaries and facilities which operate with varying degrees of autonomy. Many of these various holdings are similar in product and process but separated by geography and under different management. For these firms, the diffusion of innovations to all potential users may not be instantaneous. Minor innovations may be buried deep within one part of the company, never to be used to improve operations in other parts of the firm.

The Focus of The Research

The major thrust of this research is to determine the extent to which the improvements to operations from minor innovations in one part of a firm actually do diffuse or have the potential to diffuse to other parts of the firm. Three areas for definition are important in this regard: first, what is a minor innovation; second, who are the innovators and potential users in the firm; finally, what constitutes actual and potential diffusion. This thesis also examines some factors that may influence diffusion of minor innovations within firms.

Minor Technical Improvements

In this research, MTIs are mostly stand-alone, embodied technological changes to operations that have improved operations. These innovations tend to be the inventions of hardware commonly associated with the term "technological innovation". The disembodied changes to operations associated with how an innovation is used, such as the changes in skill levels associated with new technology, are not examined. All innovations in this research are process improvements as opposed to product improvements.

To distinguish the innovations used in this research from more general terms such as "technological innovation", the term "Minor Technical Improvement (MTI)" is used to describe each incident of minor innovation. Although minor innovation has been associated with being a prelude or epilogue to major innovation, no such claim is made in this research. MTIs are further defined as Productivity-Improving MTIs (PMTIs) and Quality of Working Life-Improving MTIs (QMTIs) in order to highlight both the economic and humanistic motivation behind the improvements which may be required or desired in a firm's operations.

Operating Units Within A Firm

This research concentrates on the diffusion of MTIs between operating units of the same firm. Each operating unit is physically separated from other operating units. Each has its own specific management team. Each has a specific mission to produce a product with its processes.

Conceivably, an operating unit could be a plant, complex, or property of any large firm. In this research, the operating units are a number of mills and mines of a large mining company.

In this thesis, an operating unit that innovates an MTI is called an Originating Operating Unit (OOU). The OOU is the first operating unit to use a specific piece of technology within the firm. The technology involved in the MTI may be new to the firm but not necessarily new to other firms. From the perspective of the operating unit, the first-time purchase of a supplier firm's technological product is an innovation. It would be credited to the OOU if it was the first operating unit documented as using the technology in the firm. An operating unit which may have adopted another operating unit's MTI and/or is considering the use of that MTI is called a Non-originating Operating Unit (NOU).

Actual and Potential Diffusion of MTIs

This research is concerned not only with how many NOUs were using an MTI but also how many more could potentially use the same MTI. In order to fully understand the extent of operating improvements possible due to the diffusion of

MTIs, some estimate of how far MTIs could spread before they had saturated all potential users had to be made. The extent that an MTI had diffused at the time of the field study was measured. A second measure was taken to determine how far MTIs could potentially diffuse.

This thesis explores the influences on why an MTI does or does not diffuse. A number of factors are hypothesized as potential influences. The degree of similarity between the NOU and OOU in their operations may determine whether an MTI is compatible and thus diffusable. OOUs and NOUs which are separated by large geographic distances may find diffusion difficult. The more distantly two operating units are related in an organization, the less likely they may be brought together to exchange MTIs. Some literature on diffusion for major innovations would suggest that the more similar OOUs are to NOUs, the greater the communication and thus the potential for MTI diffusion. The age of an MTI may affect whether it will be accessible enough or current enough technologically to be of use to an NOU. PMTIs may be more attractive than QMTIs. All these possible influences on the diffusion of MTIs within firms are examined in this thesis, but they are no means exhaustive of all possible influences.

The impact of MTI diffusion on operating improvement is examined two ways. First the costs and benefits, both in terms of productivity and QWL, are approximated for individual MTIs as used in the originating operating unit. Then the potential costs and benefits to all operating units as the result of MTI diffusion are calculated. The final results contrast the net benefits of MTI diffusion to all potential users versus use by only the originating operating unit.

Overview of the Research Design

An objective of the research design was to get an accurate and detailed account of actual and potential diffusion of MTIs within a firm. To this end, a four-month field study of on-site interviews and follow-up surveys was planned and implemented in Noranda Corporation, a large Canadian resource-based firm. The resulting data were used to test a series of hypotheses about the actual and potential diffusion of MTIs.. A wealth of other data were used to examine how MTIs were innovated and their actual and potential impact on operating improvement.

Seventy-three MTIs were selected by personnel from 13 operating units. The MTIs sampled represented a mixture of

QMTIs and PMTIs. All were considered by their OOU s to be successful examples of the MTIs used in their operations in the last five years. Thirty MTIs were documented on video tape. Forty-three were described in writing and compiled in a booklet. In each operating unit, three to five people, representing a cross-section of the operating unit's personnel, selected the MTIs from their own unit to be used in the sample. The same individuals also reviewed the video tape and written descriptions of MTIs from other operating units under the supervision of the researcher. They were asked to indicate whether they were actually using or could potentially use these MTIs.

The research site, Noranda, is one of Canada's largest corporations with various subsidiaries and associated companies across Canada and the United States. This research received the cooperation of the employees of the mine and milling operating units of the firm's various mining holdings. The 13 participating operating units consisted of seven mines and six mills. The mines were similar in that they extracted minerals from the ground. The mills were similar in that they processed rock into metallic concentrate. The operating units were spread across central and eastern Canada within six operating divisions which were in turn part of three regional divisions.

The mining industry in Canada has been undergoing economic hard times in the 1980's. Noranda's response to these conditions was typical of other firms in the industry. It had attempted to be innovative in managing people and technology to improve operations, while at the same time controlling costs. In order to improve operations, firms such as Noranda were actively pursuing employee involvement as a possible source of continuous innovation and operating improvement. During the course of the field study, the impact of employee innovativeness in inventing and innovating MTIs was frequently noted. Also noted was the improvement to operations that resulted from the accumulation of these MTIs. With continual erosion of prices for metals on world markets, an accompanying need for continuous operating improvement has been felt across the industry. These operating improvements involve increasing the productivity of resources of people, capital and materials, as well as removing impediments to productivity such as poor Quality of Working Life for employees.

Outline of Chapters

CHAPTER 2 contains a selective review of the literature on technological innovation and its diffusion. Previous work on the importance of minor innovation is presented. The literature on the diffusion of innovation is examined for evidence that minor innovations diffuse within firms. Useful ideas about what influences the diffusion of major innovations between firms and other organizations are identified. The chapter ends with some research questions left unanswered by the literature and which this research attempts to address.

CHAPTER 3 presents hypotheses about the extent and influences on actual and potential diffusion within the firm. Ten hypotheses are tested about both actual and potential diffusion. The means of statistically testing the hypotheses are briefly reviewed. Data collection methods and controls on the research design are described in some detail. The methods used to record the MTIs and then present them to participating Noranda employees are reviewed. Advantages and disadvantages of the research design are discussed, as well as the actions taken to control for threats to the validity and reliability.

CHAPTER 4 describes the research site. Noranda and the participating operating units are presented in the context of their industry and its recent history. The concern within the industry and the company for greater technological innovation is briefly mentioned, as is employee involvement. A profile of the participants who selected and responded to the MTIs at each site is presented. The chapter contains the , site-specific details needed to operationalize some of the research hypotheses and methods.

CHAPTER 5 contains a description of the MTIs used in this dissertation. Descriptive statistics profile the costs and benefits, origins, age and position of the MTIs in the operating unit's production process, for the 73 MTIs used in this research. The impact of the collected MTIs on OOU operating improvement is estimated. General comments are made about the process of taking MTIs from idea to innovation, based on observations made during the research. Individual information about each MTI is presented in Appendices 1 and 2.

CHAPTER 6 contains the results of the hypotheses testing and other statistical analysis of the collected data. The results are then discussed.

CHAPTER 7 documents the important qualitative observations about MTI diffusion collected during the field work within the research site. The case histories of MTIs that actually diffused are presented and discussed. Instances in which MTIs did not diffuse are examined. The reasons are presented. The potential for future diffusion of those MTIs as well as the further diffusion of those MTIs that had already diffused, are discussed. The opportunity costs or potential net benefits of MTI diffusion in the research site are presented.

CHAPTER 8 summarizes the major findings of the research. The chapter goes on to discuss the major implications of the research on theory about the diffusion of technological innovation. The managerial implications are discussed for the research site and other firms with multiple operating units. The chapter concludes with suggestions for further research to carry forward the study of MTI diffusion within firms.

Summary

This research recognizes the importance of continual innovation in the improvement of operations. Encouraging a continuous stream of minor innovations is a means to this end. This research presents evidence of actual diffusion and the potential for even greater diffusion of these MTIs within a firm. MTI diffusion within firms can make a significant contribution to improving operations over the whole firm. The capability to innovate on this scale lies within the firm and originates from the day-to-day involvement of employees with a concern for operating improvement.

A large firm with multiple operating units fully realizes the benefits of employee innovativeness when innovations are diffused to all potential users in the firm.

CHAPTER 2

REVIEW OF THE LITERATURE

The study of innovation and its diffusion is not a new topic but it is a large area for inquiry which still requires work. Previous work in this area has been done in a number of disciplines. The economics literature has noted the importance of technological innovation to the growth and productivity of firms, industries and economies. Its focus has been on major technological innovations as opposed to minor technological innovations. The timing of a firm's adoption of a major innovation is important in assessing the economic impact of technology. The sociology literature is concerned with the communication of innovation between people and organizations, and what influences that activity. The focus here, too, has been on major innovations. The diffusion of minor innovations within firms has not been a major concern of either the economics or sociology literature. It may be a concern of interest to operating managers wishing to improve operations.

The purpose of this chapter is to position the thesis research on the diffusion of minor innovations within a firm, relative to other studies of the diffusion of innovation. The chapter is not an exhaustive review of the vast literature on technological innovation and diffusion. The chapter is a recognition of previous contributions made in the literature that have been wholly or partially incorporated into this research.

Overview of Technological Innovation

This section provides some of the more widely held definitions and ideas about technology and innovation. These are either adopted and/or modified for use in this dissertation.

The Study of Technological Innovation

A number of disciplines ranging from anthropology to industrial engineering have had a long acquaintance with the topic. Downs and Mohrs suggest the following reason for the attention given to innovation research:

> The act of innovating is still heavily laden with positive value. Innovativeness, like efficiency, is a characteristic we want social organisms to possess. Unlike the ideas of progress and growth, which have long since been casualties of a new consciousness, innovation especially when seen as more

than purely technological change, is still associated with improvement. (1)

Figure 2.1 contains an overview of the major disciplinary streams that have contributed to the study of technological innovation. (2) The differences between the disciplinary approaches are partially historical and partially related to the unit and level of analysis. With varying emphasis, all are about the who, what, where, when and why of innovation. Economists view innovation on a micro-economic level as a number of rational adoption decisions made by individuals in response to market forces. The "individual" is often a hypothetical consumer or firm. On a macroeconomic level, innovation is a phenomenon affecting the aggregate behavior of these individuals as members of an economy. The ultimate goal is to guide government economic policy on a national or international level. Industrial engineering tends to look at the innovativeness of systems. This approach views innovation as a project management process. The level of analysis is the firm or organization with the project. Political science is mainly concerned with the innovative actions and responses to innovation of large decision-making interests such as government and the targets of government policy. The level of analysis is usually sectoral, national or international. Psychologists have researched innovation

FIGURE 2.1 - Overview of Major Disciplinary Streams For Technological Innovation

DISCIPLINARY APPROACHES TO INNOVATION

	ECONOMICS	ENGINEERING	POLITICAL SCIENCE	PSYCHOLOGY	SOCIOLOGY
FOCUS	ORGANIZATIONS AS ADJUNCTS TO MARKETS EFFECTS OF INNOVATION	ORGANIZATIONS AS TOOLS FOR PERFORMING PREDEFINED TASKS THE PRODUCTION PROCESS	PURSUIT OF INTERESTS THROUGH FORMATION OF GROUPS DISTRIBUTION OF INTERESTS AS RESULT	INDIVIDUAL COMPONENT OF HUMAN BEHAVIOR HOW PEOPLE RELATE IN GROUPS	SOCIAL STRUCTURE OF GROUPS IMPLICATIONS FOR GROUP AND INDIVIDUAL BEHAVIOR
PRIMARY CONCEPTS	MACRO AND MICRO-SYSTEMS ASSUMPTION OF RATIONAL ACTION	COMPONENT INTEGRATION ADJUSTMENTS TO ADDRESS COMPONENT FAILURE	INTERPLAY OF INDIVIDUAL AND GROUP INTERESTS CONTROL MECHANISMS AND KINDS OF INTERESTS	PERSONNEL SELECTION EMPLOYEE MOTIVATION GROUP DYNAMICS	PERMANENT ASPECTS OF ORGANIZATIONAL STRUCTURE ITS EFFECT ON OUTCOMES
POLICY CONSIDERATIONS	EFFECTS OF POLICY ON MACRO INDICATORS SUCH AS G N P	RELATIVE EFFICIENCY OF VARIOUS MEANS FOR ACHIEVING PRODUCTION PURPOSES	IMPACT OF GOVERNMENT DECISIONS DECISION-MAKING METHODS HOW DECISIONS IMPLEMENTED	UNDEVELOPED ISSUES WHERE DEPENDENT VARIABLE IS ASPECT OF INDIVIDUAL BEHAVIOR	GOVERNMENT ACTION AND NONMONETARY REWARDS POWER STATUS ETC
METHODOLOGY AND MODELS	ARCHIVAL SOURCES CONCEPTUALLY DRIVEN INFERENCE REDUCTIVE MODELS	OBSERVATION REDUCTIVE MODELS	SURVEYS RELIANCE ON ARCHIVAL SOURCES PROCESS MODELS AGGREGATED CONCEPTS	SURVEYS AND OBSERVATION SOCIAL EXPERIMENTATION DIS-AGGREGATED MODELS	ORIGINAL DATA COLLECTION CAUSAL INFERENCE STRUCTURAL MODELS
MEASUREMENT AND ANALYSIS	RIGOROUS HIGHLY QUANTITATIVE EMPHASIS ON TIME SERIES	CONSUMPTION AND EFFICIENCY QUANTITY OF OUTPUT	EITHER EXTREMELY QUANTITATIVE OR EXTREMELY IMPRESSIONISTIC	MULTIPLE MEASUREMENT AND SCALING QUANTITATIVE AND QUALITATIVE	RIGOROUS MEASUREMENT HIGHLY QUANTITATIVE

SOURCE:
National Science Foundation (NSF), <u>The Process of Technological Innovation: Reviewing the Literature</u> (Washington: National Science Foundation, 1983)

from the perspective of the individual and small group dynamics. Sociologists focus on the role of groups and individual behaviors associated with innovation within those groups. Sociology addresses many levels of analysis in organizational structures and society.

An operations management perspective on technological innovation does not fit neatly into any one disciplinary stream. Depending on the operating manager's position or individual circumstance, what is relevant may vary. Operating managers may be responsible for the whole firm, as is a vice president of production. Alternatively, the operations manager may be responsible for a department or one facility as in the case of a superintendent or a plant manager. The manager may be concerned about the national economy and the innovativeness of an industry. The operating manager may be concerned about the innovativeness of individual employees and groups involved with the production process. Arguably, the latter concern is more susceptible to the individual manager's control and is the one that he or she is held responsible for by superiors and the shareholders of the firm. In this thesis, the operations management perspective on technological innovation and specifically, diffusion, is that new technology and its diffusion within the firm is an issue that should be addressed by the top management in a firm that has authority over multiple operating units.

Defining "Technology"

Schon defines technology as, " any tool or technique, any physical equipment or method of doing, for making, by which human capability is extended."(3) This definition includes ,the "hardware", such as capital goods, as well as the "software", such as operating procedures. A broader definition by Perrow includes, "work done in organizations."(4) Perrow includes social factors and organizational structure as elements of technology.

The common perception of technology as hardware, and technological innovation as new hardware, is misleading. Innovation is also new ways of managing the production process, such as Materials Requirement Planning (MRP) and Just In Time (JIT), that may require new hardware to be successful. In this research the focus is on acts of innovation or the use of "new" technology in this broader sense.

Defining "Innovation" as a Process

Utterbach defines an innovation as a unit of technology applied for the first time.(5) The implication is that the technology is new to a particular situation. "Newness" or "first time" is a perceptual matter according to Rogers and Shoemaker. (6)

> It matters little, so far as human behavior is concerned, whether or not an idea is 'objectively' new as measured by the lapse of time since its first use or discovery. It is the perceived or subjective newness of the idea for the individual that determines their reaction to it. If the idea seems new to the individual, it is an innovation.

The National Science Foundation in its 1983 survey of the technological innovation literature suggests that the determination of whether a unit of technology is an innovation depends on which stage it is perceived to be at in a process of innovation.(7) In stage-process models of innovation there are three basic stages, although different researchers use different names for each stage and often add intermediate stages in their models. The first stage in these models is usually Invention. Invention, according to Schmookler occurs when an idea is transformed into " a) a new combination of, b) pre-existing knowledge which, c) satisfies some want."(8) In the second stage, an invention is used for the first time and becomes an innovation. In the third stage, an innovation is diffused to users. Diffusion, alternatively called imitation, transfer or dissemination, can be defined as the act of spreading an innovation throughout a population of potential adopters.

The process of invention to innovation to diffusion, as presented above, implies a one-way linear relationship. This is a simplification of reality. The relationship between stages can be reciprocal. A piece of production equipment may not be an innovation to the producer but could be considered an innovation to the user who applies it for the first time in his operations.

Robins and Milliken place technological transfer and diffusion as an essential interconnecting concept between stages:(9)

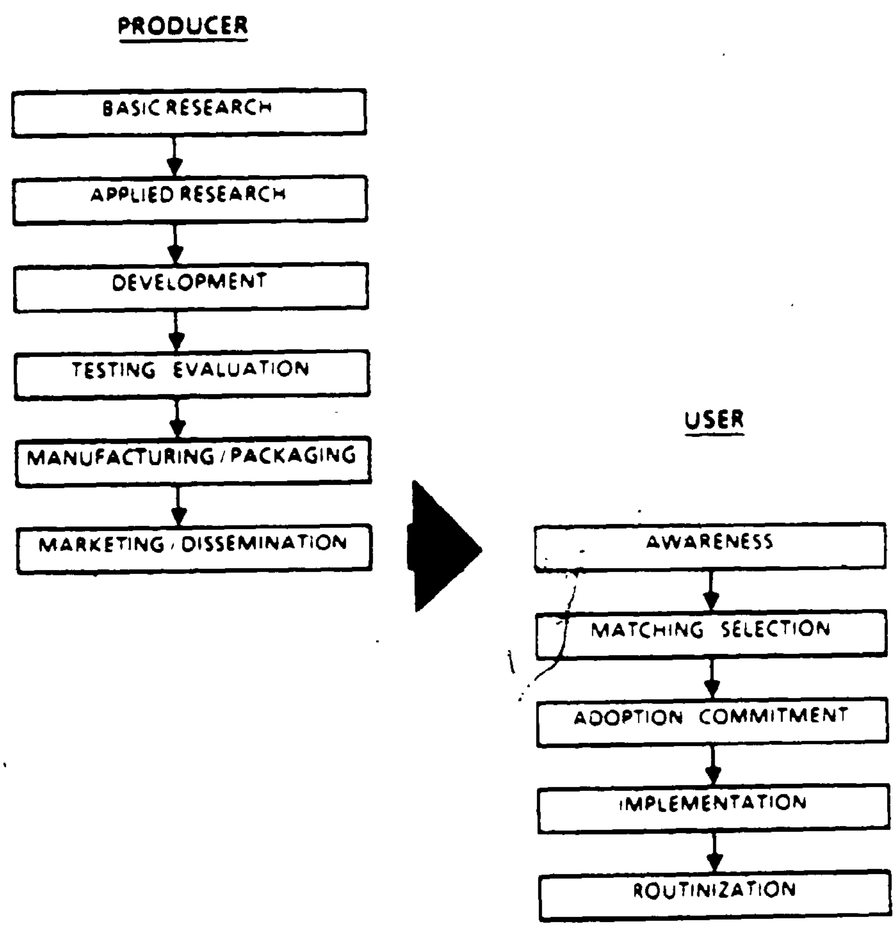
> Whether it be transfer or innovation, we can describe the process in the simplest of terms as consisting of three functions: (1) the technology must have a source; (2) the technology must be produced or manufactured; and (3) the technology must be applied or used in some socially or economically profitable way. In all cases, a movement or 'transfer' must occur from one function to the next. When such a movement does not occur, we have an unsuccessful innovation process.... These three functions and movement between them are essential to the innovation or technology transfer process no matter whether we are discussing the first application of a new technology in a new setting, or the tenth application of an old technology in an old setting.

The individual, department or firm participating at each stage may be different for a given piece of technology. The inventors, innovators or adopters of a new piece of technology are often each engaged in their own personal innovation process as they confront a new situation.

A simpler conceptualization used in this dissertation is that innovation involves a dual process with both a producer and user perspective. Figure 2.2 contains a modified version of a National Science Foundation conceptualization of a dual innovation process.(10) The two processes are not always independent of each other, although the producer perspective usually occurs sequentially before the user perspective. Producer and user interaction may be critical during the successful development of technology, such as when suppliers work with customers to custom design or fit their product to the customer's specific needs.(11) The interface between producers in the marketing/dissemination stage and users in the awareness and matching/selection stages is examined closely in this research.

In this research the confusion between who is the producer or user of an innovation is avoided by the designation of Originating Operating Units (OOUs) and Non-originating Operating Units (NOUs). The OOU is the producer within the firm of an innovation. The NOU is the user within the firm who has adopted an innovation from an OOU or is considering potential adoption at a future date. To avoid confusing this research with other research into the

FIGURE 2.2 - Dual Innovation Process



SOURCE:
Modified by the researcher from:
National Science Foundation (NSF), <u>The Process of Technological Innovation: Reviewing the Literature</u> (Washington: National Science Foundation, 1983).

adoption of innovation by firms in an industry or economy, the term "use" is substituted for "adoption". An OOU may adopt another firm's product or process which represents the first use of that technology in the firm. NOUs may subsequently use that technology from the OOU in their operations.

Defining the Unit of Analysis for Diffusion Studies

Tornatzky et al. suggest that one of the unreconciled questions in research into the innovation is: "What is the proper unit of analysis for examining the innovative process, or rather, who are the 'actors' involved, and what degree of autonomy do they exercise ?" (12) This dissertation adopts the convention for defining the unit of analysis in innovation studies suggested by Mohrs and Downs.(13) This unit of analysis is the individual innovation (the MTI) in the context of the individual organization. Mohrs and Downs used this unit of analysis in what they called an innovation-decision design.

An organization does not usually have a blanket response to innovation. Some innovations have merit; others do not. Organizations make decisions about adopting MTIs on a case by case basis. Labeling an organization as an innovator or, at the other extreme, a laggard in the adoption of technology, based on a tally of when and how many innovations are adopted, is not useful for the individual organization or operating manager. The decision to use one of many MTIs available to an NOU is all that is needed to begin to incrementally improve an NOU's operations. This thesis is concerned with how many innovation decisions by NOUs represent actual diffusion or have the potential for diffusion.

The "actors" involved in an organization's innovation decision about the usefulness of an innovation can be numerous and from various levels in the organization. For MTI-type innovations there may be a number of people involved in the development of an MTI within an OOU and the decision to use it in an NOU. There is evidence suggesting that the involvement of supervisors and managers as change agents acting as technological gatekeepers, boundary spanners and product champions can be important to successful innovation. Managerial and supervisory personnel tend to act as technological gatekeepers filtering and transmitting information to subordinates. Roman et al. report that subordinates' responses to the information in terms of innovative behavior will vary with the sub-culture or sub-system and the specific technology being considered. (14) According to Aiken et al., people positioned lower in the organization will generate more technical improvement proposals if they are given, by management, greater exposure to contacts outside the immediate organization and greater influence in the decisions concerning new technology. (15) In this thesis, a representative group of operating unit employees including workers, supervisors and management, were used at each operating unit to speak on behalf of the operating unit regarding the actual and potential use of MTIs.

A popular approach in the innovation literature has been to study the relationship between the personal attributes of individual decision-makers and early or late adoption. An individual who is a frequent early adopter of innovations is considered an innovative decision-maker. Among the trademarks of such people are, higher social status, more favourable attitudes towards credit, change, risk, education, and sciences, greater intelligence, more social participation, more change agent contact, more exposure to mass media and interpersonal communication channels, less fatalistic views, more cosmopolitan backgrounds, more highly integrated links with the social system, and more information and knowledge about innovations. (16) (17) The psychometric testing and weighting of a list of traits of innovative individuals is outside the specific focus of this thesis.

The focus in the literature has been on the manager as the decision-maker. In this research, managers were not found to be the only individuals with input into an innovation decision. While this thesis was not concerned with the influence of the characteristics of individuals on innovative behaviors, it was concerned with identifying individuals who influence the actual diffusion of MTIs within the firm or could potentially do so. This thesis approaches innovation decisions as the product of input from a number of people in an organization.

The Role of Innovation in Improving Operating Performance

Economists have experienced considerable difficulty in determining the precise impact of technological innovation on whole economies. Rosenberg's definition emphasizes its consequences. Technological innovation is "certain kinds of knowledge that make it possible to produce, (1) a greater volume of output or (2) a qualitatively superior output from a given amount of resources." (18) How technological progress in an economy occurs has long been debated. Schumpeter saw technological innovation as "perennial gales of creative destruction", produced by radical technological innovations creating major changes in the economy.(19) Fishlow and Hollander view technologically driven progress as an accumulation of minor improvements and modifications punctuated by occasional major innovations. (20) (21) Economists such as Kendrick, Denison and Solow in accounting for the significant improvements in the overall productivity of the North American economy, suggest that technological innovation is one of the important factors. Researchers into productivity such as Kendrick and Denison attribute as much as 40% to 50% of changes in total factor productivity in the twentieth century North American economy to technological innovation.(22) (23) Technological innovation is contrasted to just "technology" alone. The former involves changes that improve the productive use of resources, rather than using more. This kind of accounting is controversial. Factors such as changes in quality of product and process are difficult to enumerate. What is agreed upon is that technology has improved the productivity of the North American economy essentially by expanding output and lowering labour intensiveness through the substitution of capital.

Technological innovation is a popular management variable often mentioned in association with productivity improvement. Technological innovation translates into activities focused on the development and adoption of new hardware and associated embodied technology. Judson's 1982 survey of high level management attitudes towards productivity presented the view that capital investment in plant equipment and process was the favourite means of improving the productivity of the whole firm.(24) Five years of annual productivity surveys by the Institute of Industrial Engineers have identified the most frequently cited productivity improvement activity as the adoption of technological hardware and software. (25) This is also considered the most effective productivity improving activity. However, productivity improvement by technological innovation has its limitations, at least as it applies to major capital-intensive technology. Gale suggests that a business may be a poor candidate for mechanization, resulting in serious losses to profitability for only small gains in labour productivity, if it is in a poor strategic position relative to its environment.(26) An ideal candidate has a high market share, low rate of new product introduction, is non-unionized, has high capacity utilization, rapid real market growth and differentiated products. Unfortunately, not all firms fit this ideal profile.

The meaning of operating performance goes beyond profitability, low unit costs and high labour productivity. If the operations of a firm can be defined as a configuration of resources combined for the provision of goods and services, then conceivably performance has to be stretched to cover many functions and levels in a firm.(27) Performance has many dimensions. In his conceptualization of organizational systems performance, Sink cites seven distinct, inter-related measures: effectiveness, efficiency, quality, productivity, quality of working life, profitability and innovation.(28) In this dissertation, innovation, productivity and quality of working life are considered important dimensions of operating system performance.

The Definition and Importance of Minor versus Major Innovations

This section presents minor innovation as an important part of a firm's evolving operations. Previous work defining minor innovation and its impact on operations is surveyed. The operationalization of minor innovation in this thesis is called Minor Technical Improvement (MTI). Its definition is partially derived from the literature.

Major and Minor Innovation in The Evolution of the Firm

Abernathy and Utterback proposed a model to capture the changing nature of product and process changes in firms over time.(29) From its start-up as a small entrepreneurial organization, to one with a mature product and process, a firm passes through three patterns of innovation. The first is a fluid pattern of frequent major changes in products as the young firm struggles to find a market and grow. The second is a transitional pattern of major process changes required by rising volumes. The third is a specific pattern of innovation of incremental product and process changes resulting in cumulative improvements in productivity and quality. The specific pattern in a mature industry of incremental innovation often represents the only economically viable option. In those industries, the markets are not available for risky major innovations and meticulous cost reduction is the order of the day.

As a firm evolves from a pattern of major or radical innovation, the fluidity of its organizational structure and the motivation for innovating also changes. The rigidity of standardized processes formalizes organizational structure and purpose. This transformation tends to suppress major innovation. To what degree the flow of minor innovation is affected at this stage is not known. In evolving to the form needed to compete and remain relatively productive as a maturing firm, the firm loses the innovative capabilities that allowed it to compete as an entrepreneurial venture. This is the essence of Abernathy's "productivity dilemma". (30) Rekindling innovation in large firms in mature industries may begin with recognizing the importance of minor technological innovations at that point in the firm's evolution.

Significant Work About Minor Innovation

Minor innovation has been cited frequently as the prelude and epilogue to major innovation. Fewer works have focused on minor innovation as a subject for study in its own right. In the 1980's, managers are aware of minor innovation as output from programs such as Quality Circles and similar productivity improvement programs. The studies referred to in this section are some of the major works specifically addressing minor innovation.

HOLLANDER (1965)

In his 1965 study of the impact of technical changes in five DuPont Rayon plants over the course of 30 years Hollander discovered:(31)

> Continuous effort was exerted to reduce unit costs by means of minor technical changes at the plants investigated. The cumulative effect of the minor

> technical changes was in fact greater than that of the major changes.

It should be noted that Hollander uses the term "minor technical change" to get around the narrowness of past definitions of "innovation" used by early researchers in the field, such as Schumpeter, who excluded diffusion and minor innovation from his definition.(32) Hollander's work added to an earlier study by Enos that found that the cost reductions associated with minor improvements subsequent to major innovations often exceeded those associated with the initial implementation of the investment. (33)

Minor innovations are contrasted to major innovations in Hollander's work primarily on the basis of individuals recalling, after the event, the degree of difficulty in developing the innovation prior to its first successful use. Hollander's definition of minor versus major technical change is not a function of the effect on unit costs of the technological innovation or the investment expenditures required to develop it. Minor technological innovations usually involved an evolutionary alteration in the existing tools and techniques and for this reason were relatively simple to implement. Major change involved a significant departure from existing methods and were therefore "relatively difficult" to accomplish. The riskiness associated with the uncertainty of costs and benefits common with major technological innovations was considered non-existent with minor technological innovations. Major innovations tended to be associated with changes that resulted in increased output and the cost improvements associated with economies of scale. Minor innovation tended to be associated with cost reduction and keeping the operations "out of trouble". No mention is made of disembodied technological changes in what was essentially a process of installing and modifying new capital equipment.

Hollander found that technical assistance groups within each plant, made up of plant employees, played the most important role in the development of minor technological innovations. The DuPont engineering department and suppliers played a supporting role. The major technological innovations were, for the most part, dependent on the central DuPont research and development center, although the technical assistance groups played an important supporting role in making the technology work. Technical assistance groups within each of the plants tended to be made up of people with technical backgrounds, such as chemists. No mention was made of the specific pattern of diffusion of minor innovation between the plants or who might be responsible, although it was implied that minor innovations from one plant were implemented in other plants. Major technological innovations were documented as originating or being passed on by the central research and development facility.

MYERS AND MARQUIS (1969), MARQUIS (1969)

In their examination of 567 process and product innovations from 121 different companies within five industries, Myers and Marquis noted that: "Technical change is, to a significant extent based on the cumulative effect of small incremental innovations."(34) (35) Minor, in contrast to major, technological innovations were smaller, cheaper and caused very little disruption in the firm's production processes. Two-thirds of the innovations Myers and Marquis studied had an initial cost under $100,000(US). One-third of the total sample were modifications of existing products or processes (140 were process innovations). Almost half required little or no modification in the firm's production process.

A reworking of the Marquis and Myers's study produces evidence that approximately 66% of the process innovations originated from within the firm. Myers and Marquis indicated that this finding may have been the result of a "not-made-here" bias on the part of contributors to the study. The key information inputs which were used by the innovator to develop the innovation originated in 50% of the cases from outside the firm. In the other 50%, the key information input came from the personal experience of the innovator. Unknown from the study's data was the exact portion of minor technological innovations of a process nature originating from within the firm.

OTHER RESEARCH

In a 1984 study of innovation in the computer industry, D. Sahal found: "The cumulative impact of several incremental innovations on technical progress in the computer industry has been at least equal to the impact of the radical innovations."(36) Sahal's confirmation of earlier work further reinforces the generalizability of the importance of minor technical change or innovation as a class of technology to be examined in the consideration of technological innovation. In his overview of the innovation literature, Rothwell noted:(37)

> Most innovation studies have focused exclusively on major, or radical innovations, and have ignored the role of incremental, or minor innovations. ... Further, it might also be that the circumstances surrounding the generation of successful major innovations are significantly different from those surrounding the generation of minor innovations. This would have important policy implications for management since it is extremely important from the view of resource allocation to know what type, and what level, of resources to devote to the different kinds of innovation.

Definition of Minor Technical Improvement (MTI)

The term "Minor Technical Improvement" (MTI) is used to define the group of minor innovations studied in this research. The definition encompasses some of the ideas expressed about minor innovation in this section. The following distinctions were made:

a) An MTI is a separate piece of technology which is in itself capable of being diffused. Whether it is or is not derivative of a major innovation is not considered important for this research.

b) An MTI can be both embodied and disembodied technology.

c) The objective of adopting an MTI is not only productivity improvement and cost reduction but also an improvement in the quality of work life (QWL) as measured by health, safety and job design factors.

d) An MTI is a change in the operating system that has a positive impact on the improvement of operating performance, as measured by productivity and cost measures and perceived changes in the quality of working life.

The parameters, partially derived from the literature, used to operationalize the term MTI for selection purposes are:

a) The total initial outlay for the development and implementation of the first working version of an MTI in the production process is less than $30,000. If the signing authority for capital and program expenditures of the operating unit manager is less, then the signing authority becomes the limit.

b) The technology involved in the innovation has not been used by the operating unit before.

c) The technology is relatively easy to implement without major change or disruption of the basic production process.

The Diffusion of Innovation

The study of the diffusion of innovation is a sub-domain of the technological innovation literature. Its major roots are in disciplines other than those that address directly the interests of operating managers. The innovations discussed in the research literature often represent historic major changes in technology. The focus has been on the impact of these particular technologies on industries and economies. In this section, the diffusion of minor innovation within firms is identified as an underdeveloped area in the diffusion literature. Ideas in the existing literature about influences on diffusion are presented.

Diffusion as a Problem in Innovation

Allen, Tushman and Lee in 1979 and Sahal in 1981 suggest that the transfer of major technology tends to be delayed or defeated by factors that differ between the unit of origin and the potential user.(38) (39) Where science is considered universal, technology is highly localized in the problems experienced by the organization under examination. This is the essence of Sahal s term "technological insularity". To quote Allen:(40)

> Technology is highly localized in that problems are defined in terms of the interests, goals, and local culture of the organization in which they are being attacked. Similar technological problems may become defined in very dissimilar ways by organizations working on them because these organizations often have different objectives and value systems.

Sahal outlines the difficulty associated with the diffusion of technology with such localized tendencies.(41) .

> The implication is that there are built-in obstacles to the transfer of technology, since innovations depend not so much on knowledge imported from without as they do on experience from within. ... It is to a considerable extent both product and process specific. This is not to say that it cannot be effectively transferred from one organization to the other. Rather, success in technology transfer hinges upon meticulous alterations in the design of the chosen technique to suit the requirements of the differing production systems. The transfusion of technical know-how across system boundaries is therefore invariably a costly and time consuming process.

The flow of new technology across system boundaries, whether those of an operating system or some other level of socio-technical organization such as work group, is not instantaneous or uniform. According to Sahal, three factors govern this effect and are in fact obstacles to diffusion: (42)

1) The Cost of Search Activities. Not all technology is readily available for quick acquisition. A large element of latency in technology makes it something that has to be "ferreted" out.

2) The Cost of Adaptation. The cost of adapting specific technology to specific uses may be too great.

3) The Scope of the Innovation. Technology innovations are assimilated gradually rather than in large units. A piece of technology can represent too great a leap for the capabilities of an organization.

Both Sahal and Allen et al. primarily discuss major product and process technological innovations. Sahal was concerned mainly about the transfer of new technology between industries and economies. Allen et al. were concerned about the transfer of complex technological information within and from outside a large R&D organization. Both authors recognize the importance of incremental or minor technological changes but extend no comment about their pattern of diffusion or transferability. Sahal does recommend that success of technological innovation is a function of scale and learning. He defines scale as being the appropriateness of the technology to adapt to the task environment and learning as whether the technology is amenable to modification and upgrading. Both these factors may be significant determinants of whether major innovations will diffuse.

Sahal's and Allen et al.'s insights about the resistance of major innovations to diffusion may not be appropriate for MTI diffusion within firms. First, the internal communications within firms should be avenues for quicker and more frequent search activities. Second, MTIs are not overly complex in design and implementation, therefore the costs of adaptation should be minor. A potential user could adopt a "take it or leave it" attitude with MTIs rather than be concerned about adaptation. Finally, MTIs are small discrete units of technology which should not be difficult to assimilate. Scaling and learning therefore may be non-issues in MTI diffusion.

For minor innovations, diffusion may hinge more on the costs, in time and money, of ferreting out MTIs, given that they may be hidden deep within an organization. A decision to use an MTI does not come about unless contact is made between innovator and user. The expense of searching out an MTI, relative to the benefits of using it, may dissuade search activity by the potential users. The tendency would be then for the potential user to incur the opportunity cost of not searching for useful MTIs and/or the out of pocket cost of re-inventing or re-innovating a similar MTI.

Research Traditions in the Diffusion of Innovation

The spread of technological innovation has been researched from the perspectives of economics, engineering, political science, psychology and sociology. There is little standardization of the many concepts and terminology used across disciplines of similar ideas. The disciplinary streams overlap into four loosely defined traditions of diffusion research. Once again, as in the overview of the technological innovation literature, the unit and level of analysis is the key to understanding how each area differs from the others. Figure 2.3 contains a summary of the relationship between major areas of current research and the disciplines active in the area.

Studies of the diffusion of technological innovation concentrate on the successful adoption of innovation. Sociologists such as Rogers and economists such as Davies have used the firm as the unit of analysis but have attempted to aggregate the behavior of firms to talk about technological transfer on a national and international level.(43) (44) Economists have done little to address the decision-making involved inside the firm which determines adoption or non-adoption. Sociologists have been more rigorous in exploring innovation within the firm and other forms of so-

FIGURE 2.3 - Current Research in Diffusion and The Discipline Involved

Disciplinary Stream	Focus of Research			
	Diffusion of Technological Innovation	Innovation Processes	R & D Management	Purchasing/ Marketing
Economics	X			
Industrial Engineering		X	X	
Political Science		X		
Psychology		X	X	
Sociology	X	X	X	
Management of the Firm		X	X	X

X = Currently Involved

cial organization. Innovation process research encompasses diffusion as one part of a successful innovation process. It is a new area enjoying considerable cross-disciplinary activity, according to Saren. (45) In the area of management, at the level of the firm some work has been done from an industrial engineering perspective, (Twiss), and from an industrial marketing perspective (More). (46)(47) Research and Development (R&D) management is concerned with the successful transfer of information between units of analysis, which could be individuals, social groups, R&D departments or R&D departments and client organizations. One study in this area is the highly detailed work by Allen, mapping information flows between people and departments in R&D organizations. Often absent from a management point of view in this work is an assessment of the economic impact of the diffusion activities. The final area, loosely called Purchasing/Marketing, focuses on the firm and individual roles and departments within it as the unit of analysis. In this area, the purchasing/marketing interface is examined. The research question being asked is: what factors influence the succesful introduction of a new product or product line to the trade. Unfortunately, there has been little integration of the different research approaches. Klein and Tornatzky's meta analysis on the adoption of innovation is a notable exception.(49)

History of the Diffusion of Innovation

The work of Rogers, Sahal, and Davies was used to compile a brief history of the development of the major models and approaches in diffusion research.(50) (51) (52) This is not an exhaustive review of the multi-disciplinary field of diffusion research.

The first cited diffusion study was by Gabriel Tarde. In 1903 Tarde made observations about a "law of imitation" in studying the spread of innovations in manufacturing and agriculture. Tarde attempted to "learn why, given one hundred different innovations conceived of at the same time - ten will spread abroad while ninety will be forgotten." One of the "laws" he formulated was that an innovation was more likely to be adopted the more compatible it was with what the potential adopter already had. Tarde also observed but did not quantify the basic premise behind the "S" shaped or cumulative frequency curve of adoption over time. This later became a central concept in most diffusion research in economics. The logic behind the "S" or logistics curve is that at first only a few individuals accept the innovation, then the rate of adoption quickens with acceptance, slowing to a trickle as the potential adopter population is saturated.

Rogers' survey of 3,085 publications on diffusion offers an overview of the diffusion literature. Notable in his work is the dominance of the Rural Sociology research tradition. Since 1960 the distinctions between the research traditions presented in Figure 2.4 have blurred due to some cross-disciplinary research.(53) The Economics approaches to diffusion borrow heavily from the Rural Sociologists but take a more quantitative approach to defining the cumulative frequency diffusion curve and the factors affecting its shape. In his history of technical progress, Rosenberg is critical of the habit of classic economists to assume diffusion away prior to the discovery that diffusion was quantifiable.(54) The common assumption in economic modelling was that innovations were frozen in design after first use and then instantaneously diffused. Economic historians often documented who invented a piece of technology first, to the exclusion of the more important question of who within the economy absorbed the benefits of its use and when did this happen. Later, the realization that the productivity-increasing effects of superior technologies depend on their utilization in the appropriate places, led to a flurry of intensive economic study. This research is an extension and integration of some aspects of these traditions of study into diffusion applied to minor innovation within the firm.

FIGURE 2.4 - Disciplinarv Streams Traditionallv Active in The Studv of Diffusion

Diffusion Research Tradition	Number of Diffusion Publications	Typical Innovations Studied	Method of Data Gathering and Analysis	Main Unit of Analysis	Major Types of Findings
1 Anthropology	134	Technological ideas (steel ax, the horse, water boiling)	Participant and nonparticipant observation and the case study approach	Tribes or peasant villages	Consequences of innovations, relative success of change agents
2 Early sociology	10	City manager government, postage stamps, ham radios	Data from secondary sources and statistical analysis	Communities or individuals	S-shaped adopter distribution, characteristics of adopter categories
3 Rural sociology*	791	Mainly agricultural ideas (weed sprays, hybrid seed, fertilizers)	Survey interviews and statistical analysis	Individual farmers in rural communities	S-shaped adopter distribution, characteristics of adopter categories, perceived attributes of innovations and their rate of adoption, communication channels by stages in the innovation-decision process, characteristics of opinion leaders
4 Education	336	Teaching/learning innovations (kindergartens, modern math, programmed instruction, team teaching)	Mailed questionnaires, survey interviews, and statistical analysis	School systems, teachers, or administrators	S-shaped adopter distribution, characteristics of adopter categories
5 Public health and medical sociology	226	Medical and health ideas (drugs, vaccinations, family planning methods, CAT scanner)	Survey interviews and statistical analysis	Individuals or organizations like hospitals	Opinion leadership in diffusion, characteristics of adopter categories, communication channels by stages in the innovation-decision process
6 Communication	372	News events, technological innovations	Survey interviews and statistical analysis	Individuals or organizations	Communication channels by stages in the innovation-decision process, characteristics of adopter categories and of opinion leaders, diffusion networks
7 Marketing	304	New products (a coffee brand, the touch-tone telephone, clothing fashions)	Survey interviews and statistical analysis, field experiments	Individual consumers	Characteristics of adopter categories opinion leadership in diffusion
8 Geography	130	Technological innovations	Secondary records and statistical analysis	Individuals and organizations	Role of spatial distance in diffusion
9 General sociology	382	A wide variety of new ideas	Survey interviews and statistical analysis	Individuals	Characteristics of adopter categories various others
10 Other traditions†	500	—	—	—	—
Total	3,085				

*The rural sociology tradition actually includes 147 publications by diffusion scholars in extension, whose work is closely related

†Includes general economics, political science, agricultural economics, psychology, statistics, industrial engineering, and various others

Source: Diffusion Documents Center, Stanford University, in 1981

SOURCE:
E.M. Rogers, Diffusion of Innovation 3rd Ed (New York: The Free Press, 1983).

Rogers' Rural Sociology Model

Rogers defines diffusion as the process by which an innovation is communicated through certain channels over time among members of a social system.(55) In his concept of diffusion, an innovation is a piece of new technology whose nature is uncertain and thus has a certain riskiness for the potential user. Uncertainty about the innovation is reduced by innovation evaluation information in five areas. These areas are:

1) RELATIVE ADVANTAGE. The degree to which an innovation is perceived as better than the idea it supersedes.

2) COMPATIBILITY. The degree to which an innovation is perceived as being consistent with the values, past experiences and needs of potential adopters.

3) COMPLEXITY. The degree to which an innovation is perceived as difficult to understand and use.

4) TRIALABILITY. The degree to which an innovation may be experimented with on a limited basis.

5) OBSERVABILITY. The degree to which the results of an innovation are visible to other individuals or organizations.

In order to reduce uncertainty, information about an innovation is communicated through channels. A key principle effecting communication is: the greater the homophily or match between individuals, groups and organizations in terms of beliefs, experiences and education, the greater the communication.

Innovation evaluation information is communicated and input into a potential adopter's innovation-decision process to accept or reject an innovation. Rogers believes this process consists of five stages similar to the modified NSR model presented earlier:

1) Knowledge (Awareness)
2) Persuasion
3) Decision
4) Implementation
5) Confirmation

During this process, innovation evaluation information is weighed and acted upon even after the innovation is adopted and installed.

Determining how innovative an individual, group or organization may be depends on when it adopts an innovation. Rogers has five intervals, from early adopter to laggard. Innovation in Rogers' model is a process whereby individuals interacting in social groups or organizations are important in facilitating the diffusion process and determining when to adopt. Opinion leaders, defined as people with influence in a social setting (such as managers), are influenced by change agents. A change agent is a person who influences innovation decisions. A change agent can be a product champion, a boundary spanner, or a technological gatekeeper.(56) (57) (58) Allen's concept of a technological gatekeeper fits neatly into Rogers' model since they are insiders who act as conduits for information from outside an organization or social setting and who are well respected and used by other members of the same organization or social setting.

This thesis tests Rogers' belief that the more similar the individual producers and potential users, the more likely diffusion of innovation will occur. The individuals in this research are individual operating units within a firm. All five areas of evaluation information were believed to be important in how potential users in this research responded to the MTIs presented to them. However it was not possible to determine which area was more important or what the actual measure of each might be in the minds of the operating unit personnel involved.

Positioning Intra-Firm Diffusion of MTIs In The Diffusion of Innovation Literature

Intra-firm diffusion of minor innovations is the least studied area in the diffusion of technological innovation literature. It is precisely in this area that this research is positioned. Management of the production operations function may benefit significantly in its drive for operating improvement through new research in this area.

MAJOR TECHNOLOGICAL INNOVATIONS BETWEEN FIRMS

Most of the diffusion literature in the context of sociology or economics uses the firm as the the basic unit of analysis for the variable, producer or user. Firms are frequently clustered for study or comparison in industries Researchers have attempted to answer three primary questions about diffusion between autonomous individuals, groups or organizations.

1) How do early adopters differ from late adopters of an innovation?

2) How do perceived and descriptive attributes of an innovation affect its rate of adoption?

3) What is the shape of the diffusion curve that describes innovation(s) diffusion to adopters over time?

Davies divided the mainstream economics literature focusing on the diffusion of major innovations between firms into three major groups.(59)

1) INTER-INDUSTRY/ INNOVATION APPROACH: The study of one or more innovations in a number of industries. Attempts to explain in a general theory the variances in the speed of diffusion in terms of differences in attributes of the industries and innovations concerned.

2) INTER-FIRM/ INNOVATION APPROACH: The study of individual innovations diffusing in single industries. Attempts to explain differences between firms in the time taken to adopt by

firm-level characteristics.

3) INTERNATIONAL APPROACH: The study of diffusion between countries and industries crossing international borders.

The International Approach is excluded from the literature survey as outside the scope of the proposed research.

INTER-INDUSTRY / INNOVATION APPROACH. In Mansfield's pioneering work on diffusion, he looked at 12 innovations in five American industries: Iron, Steel, Coal, Rail and Brewing.(60) He hypothesized that non-adoption of an innovation would be a function of: 1) the profitability of installing the innovation relative to that of alternative investments, 2) the size of the investment relative to the assets of the firm, and 3) the proportion of firms having adopted by a certain time. These were assumptions made to create a model of diffusion from cross-sectional data collected at one point in time instead of longitudinally. Mansfield's findings supported the appropriateness of the "S" curve as both a descriptive and predictive model of innovation diffusion. Serious questions about Mansfield's methodology have been raised. Some have suggested that it uses general economic assumptions to gloss over important variables such as the role of information uncertainty and risk, as well as differences between firms that affect adoption decisions. These reservations have not stopped other researchers from using similar methodologies.

INTER-FIRM / INNOVATION APPROACH. Mansfield is also credited with the pioneering work in this area. The dependent variable, the number of years a firm waits before beginning to use an innovation, was tested against the independent variables:

1) Firm Size
2) Profitability of the Investment in the Innovation
3) The Rate of Growth in the Firm (Assets)
4) Profitability of the Firm
5) The Age of the Firm President
6) The Firm's Profit Trend

The results of the multiple regression analysis of these variables were inconclusive. The variables were not independent of each other. The selection of variables shows an adhoc approach rather than one drawn from comprehensive theory. Davies offers some statistical support for positive relationship between innovation profitability and adoption and a negative one between firm size and adoption.(61) More expensive innovations were not found to diffuse slower than less expensive innovations, as might be expected. The smaller the size inequalities between firms, the greater the labour intensity of the adopting industry and the faster the rate of growth in the adopting industry, the faster the diffusion. Major innovations as a whole were found to require on average, 14 to 15 years to diffuse to all potential adopters. No such time period was offered to describe minor technological innovations. To quote Davies: (62)

> On a theoretical level, we are nowhere near an economic model of the adoption decision: theory has been a little ad hoc and many of the variables suggested offer little explanation of the individual firm behaviors.

MAJOR INNOVATIONS WITHIN THE FIRM

The diffusion of major technological innovations within firms, or intra-firm diffusion, was considered in Nasbeth and Ray s collection of diffusion studies on process technological innovation.(63) Intra-firm data were included in order to plot a diffusion curve accounting for the portion of potential users with multiple applications of the same innovation within the same firm. The methodology used in these studies assumed that: a) there was only one decision-maker acting on behalf of the whole firm who was responsible for technological innovations and, b) the innovation originated outside the firm from suppliers, competitors and trade and research associations. This over-simplification of the innovation adoption decision process is not unrepresentative of the economic approaches to diffusion. Davies (1979) dismisses intra-firm diffusion as a trivial concern for the major innovations he examined, assuming that a) firms adopt all innovations 100%, b) later, repeat adoptions of the same or similar innovation are separate adoption decisions made independently of the previous decision, and c) there are limited data available for rigorous study.(64)

Mansfield looked at the intra-firm diffusion of one major innovation in 1963.(65) He examined the diffusion of diesel locomotives within 30 railroad companies. Mansfield was interested in determining if some of the technology and firm attributes used in inter-firm diffusion studies affected the rate and extent of intra-firm diffusion. The extent of diffusion of diesels was determined by the percentage of the total diesel stock represented by the number of new locomotives over progressive points in time. A firm was considered to have first adopted diesel technology when 10% of its locomotive stock was diesel. Diesel locomotives were believed to be fully diffused when 90% of the stock was converted to diesel. Mansfield found that there were similarities between intra-firm diffusion and inter-firm diffusion' in that both followed the cumulative normal frequency curve over time. The time when a firm first adopts a technology relative to other firms, its financial liquidity and the age of the equipment, all had positive statistically significant effects on the rate of intra-firm diffusion. Mansfield considered the study of intra-firm diffusion important in the formulation of government policy to encourage the substitution of new technology for older technology.

MINOR INNOVATIONS BETWEEN FIRMS

Davies' study of 22 successful post-war innovations, suggested two categories of technological innovation labeled Group A and B innovations.(66) These correspond to earlier definitions of minor and major innovations. Group A innovations were defined as technologically simple, probably relatively cheap and produced off-site. Group B innovations were more sophisticated, relatively expensive, and produced on a one-off basis, often requiring lengthy periods of installation at the adopter's site. The benefits and costs of the Group A items were realized over a short time period as compared to the Group B items. Group A items diffused more rapidly than Group B technology although the Group B technology had a tendency to saturate all potential users over the long run more frequently than did Group A innovations. Davies noted that Group A innovations tended to have a more "hit or miss" diffusion pattern when compared to Group B. Group A innovations were either picked up by a large number of potential users, over a short time period, or not at all.

MINOR INNOVATIONS WITHIN FIRMS

Research into the diffusion of technological innovations within firms is evident in only a few works. Works such as Allen's study have examined information flows that communicate the seeds of innovations within R&D organizations. (67) There is some information on the role of corporate R&D in enabling the process of innovation, including the spread of the innovation to the corporate operating divisions. The focus in these works is on major R&D projects. Miller and Graham in their synthesis of a Production Operations workshop on the future of research in Production/Operations Management (P/OM) posed the following research question in this area: (68)

> If one plant in a multiplant company has successfully employed a particular approach, can that success be speedily replicated in other company plants, or are top managers asking the impossible when they insist on instantaneous adoption on a company-wide basis?

Comments and Conclusions

Past research, such as that done by Hollander, supports the statement that the accumulation of minor innovations over time in a firm can add up to significant improvements in operations. Maintaining a continuous stream of operations-improving minor innovations is a characteristic of a growing and maturing firm according to the Abernathy and Utterbach model. The result is lower per unit costs and greater volumes. Other accumulated benefits of minor innovations to operations may be in the area of improved quality of working life. In this thesis, minor innovations are operationalized as Minor Technical Improvements (MTIs). MTIs are successful improvements to productivity and QWL across a firm's operations.

The literature on innovation and its diffusion has not focused on the issue of minor innovation diffusion within firms. Diffusion is discussed mainly in the context of whole economies or industries and their adoption of major innovations. The first time any part of a firm adopts an innovation, the whole firm is usually assumed to have adopted an innovation. The validity of that assumption is questioned by some studies into diffusion within firms, such as the one done by Mansfield. Large organizations innovating a continuous stream of smaller operating improvements may not instantaneously diffuse each improvement to all potential users in the firm.

Research, such as that by Sahal, suggests that technological innovations will be highly resistant to diffusing. The technology will tend to remain localized or specific to where it was originated. Whether this generalization about innovation applies to minor innovations is an unknown. MTIs may be responses to local problems or conditions but these problems and conditions may be common to or similar to those in other locations. The volume of MTIs that exists at any point in time in an operating unit, coupled with the portability of MTIs, makes the likelihood of diffusion of at least some MTIs a possibility.

Research into the diffusion of major innovation between firms has mainly looked at successful adoption after the fact. The potential adopters of an innovation tend to be defined as the total population of an industry or interest in the firm. The assumption is often made that a rational adoption decision is made at some point in time by each member of that population. The antecedent condition for that decision is that the population of potential users is aware of the innovation. The blanket assumption that everyone in a firm is aware of the potential for using an MTI may not be a practical assumption for achieving the diffusion of MTIs within firms. Without determining accurately who are the potential users, it is difficult to determine to what extent an MTI and its associated benefits have diffused or could diffuse. In this thesis both actual and potential diffusion of minor innovations within a firm are examined.

The literature on the diffusion of innovation contains a number of studies testing for the existence of variables that influenced potential adopters in their decisions to adopt major innovations. The results have been inconclusive. Some researchers in the study of innovation may have been too ambitious in their multi-innovation, multi-industry research designs. Their objective was to progress innovation research towards a theory of innovation generalizable across technologies and organizations. A number of researchers in diffusion, such as Rothwell and Mohrs and Downs, have remarked that the "net" has been cast a bit too widely without careful consideration of the differences between firms, industries and technology. (69)(70) Considerable instability in the weighting given to variables supposedly affecting diffusion can be found when studies are compared on an attribute by attribute basis.

There are numerous research questions to be asked about the diffusion of innovation. They have not been asked as frequently, if at all, with regards to the diffusion of minor innovations within firms. A number of relevant managerial research questions should be asked regarding the diffusion of minor innovations within firms. Four basic research questions are examined in this thesis.

1) To what extent do MTIs actually diffuse?

2) What is the potential for further diffusion of MTIs?

3) What are some of the influences on the diffusion of MTIs?

4) What are the implications of MTI diffusion for operating improvement?

Unfortunately, the existing literature does not provide answers to these questions. The weight of opinion in the literature tends to suggest that minor innovations are trivial or localized phenomena which do not often diffuse or are not of sufficient value to be worth diffusing. The contribution of this research to the literature and the practice of production/operations management lies in attempting to answer these questions directly. The study takes advantage of the rich source of information provided by field work conducted in a large firm with multiple operating units to make a contribution to the literature by beginning to resolve some of the grey areas about the diffusion of minor innovation in firms with multiple operating units.

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CHAPTER 3

HYPOTHESES AND RESEARCH METHODOLOGY

The diffusion of minor innovations within firms has not been widely studied. There remain unanswered questions of relevance to production/ operating managers trying to improve the productivity and quality of working life in operations. Four research questions are addressed in this thesis: how many minor innovations or Minor Technical Improvements (MTIs) actually diffuse within a firm, how many could potentially diffuse, what are some of the influences on actual and potential diffusion and what are the implications of MTI diffusion for operating improvement?

This chapter presents and explains the research hypotheses selected to address the research questions. The hypotheses are followed by an account of the research methodology used to collect the data for testing the hypotheses. This thesis does not attempt to develop and test a detailed model of MTI diffusion within firms. It does begin the process towards developing such a model by documenting the actual and potential diffusion of MTIs within one large firm with multiple operating units. The hypotheses are formulated to test a limited number of propositions about some of the influences on actual and potential MTI diffusion within firms. The use of an in-depth field study as the research methodology provided a wealth of information about MTI innovation and its diffusion within firms, in addition to what has been hypothesized.

Hypotheses About the Diffusion of MTIs Within Firms

This section contains ten hypotheses about the actual and potential diffusion of MTIs between the operating units within the research site. These hypotheses were not exhaustive in addressing all the interesting aspects of MTI diffusion found during the course of the research. For this chapter, they are stated in alternative or research hypothesis form. The statistical results of the hypotheses testing in Chapter 6 are presented with the null hypothesis being either supported or rejected. Both Chapters 5 and 7 contain interesting findings collected in the course of the research about the nature of minor innovations and their diffusion. Chapter 4 is dedicated to describing the research site, including the conventions used at the research site to operationalize measures used in the testing of the hypotheses.

The following hypotheses will be tested in this research:

ACTUAL DIFFUSION HYPOTHESES

HYPOTHESIS 1: A greater number of MTIs will be in use in more than one operating unit.

HYPOTHESIS 2: The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by the NOU.

HYPOTHESIS 3: The greater the geographic proximity between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by the NOU.

HYPOTHESIS 4: The more similar the processes between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by the NOU.

HYPOTHESIS 5: An MTI will be adopted by an NOU during a limited time period after being innovated by the OOU or it will not be adopted at all.

HYPOTHESIS 6: PMTIs will be actually used by a greater number of NOUs than will QMTIs.

POTENTIAL DIFFUSION HYPOTHESES

HYPOTHESIS 7: The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by the NOU.

HYPOTHESIS 8: The greater the geographic proximity between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by the NOU.

HYPOTHESIS 9: The more similar the processes between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by the NOU.

HYPOTHESIS 10: PMTIs will be perceived as potentially useful to a greater number of NOUs than will QMTIs.

Explanation of The Hypotheses

The following section presents the reasoning behind why the research hypotheses were stated as above.

THE ACTUAL DIFFUSION OF MTIs

The literature on diffusion suggests that technology is resistant to being diffused. This point of view comes from the study mainly of major innovations diffusing between firms. This point of view may not be generalizable to MTIs diffusing within firms. When comparing major innovations to MTIs the following differences may favour MTI diffusion:

1) An MTI is comparatively simple to understand. An informed decision can be ~~made~~ about its use after a short period of exposure.

2) An MTI is comparatively inexpensive. The cost of experimentation on the part of the potential user is not prohibitive.

3) An MTI is comparatively easy to implement with minimum disruption of the operating system. Most changes are isolated in one stage or department of the production process.

4) An MTI tends to realize its costs and benefits over a short time period. Whether an MTI performs as expected is known quickly. If the MTI continues to be used, it is most likely performing successfully.

MTIs may be more likely to diffuse between operating units of the same firm than between firms. The following differences between diffusion within versus between firms may favour the former for certain MTIs:

1) Intra-firm diffusion is not directly influenced by competitive market forces. Operating units are less likely to maintain the same organizational barriers to innovation against other operating units in the same firm as they would against other firms.

2) Lines of formal communication are more likely between operating units of the same firm. Management and technical people may transfer more freely between operating units of the same firm. Information is disseminated through the organization structure of the corporation, possibly by central agencies within the corporation.

3) Operating units within the same firm may have similar technology due to the influence of centralized control at the corporate head office, such as in the engineering and purchase of capital assets.

From the above reasoning, a research hypothesis was formulated which reflects the possibilities for actual diffusion of minor innovation.

HYPOTHESIS 1: A greater number of MTIs will be in use in more than one operating unit.

It is further proposed that an operating unit, the Non-originating Operating Unit (NOU), will use another operating unit's MTI, the Originating Operating Unit (OOU), if:

1) The NOU is aware of an OOU's MTI.

2) OOU and NOU(s) share similar process technologies, which allows an MTI to be compatible with the NOU's operations.

3) The problem or opportunity addressed by the MTI has not already been dealt with by a similar or alternative MTI or feature built into the technology of the production process by an NOU.

4) The MTI is perceived to be a satisfactory approach to a problem or opportunity by an NOU.

Awareness of an MTI in another operating unit may depend on managerial jurisdiction and geographic proximity. The lower the level of shared management between two operating units, the more likely that communication may occur about MTIs. The closer two operating units are in terms of physical distance, the more likely that communication may occur concerning MTIs. Travel time for NOU or OOU personnel may be important in getting the MTI used. Chapter 4 contains details of how geographic proximity is operationalized in this research. Time may be a factor in awareness because MTIs that are too new will not have been talked about between operating units and MTIs that are too old will have been forgotten. Management jurisdiction, geographic proximity and timing are tested as influences on actual diffusion in the following hypotheses:

> HYPOTHESIS 2: The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by the NOU.
>
> HYPOTHESIS 3: The greater the geographic proximity between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by the NOU.
>
> HYPOTHESIS 4: An MTI will be adopted by an NOU during a limited time period after being innovated by the OOU or it will not be adopted at all.

The more similar two operating units are in their operations, the more likely that MTIs from one might be compatible with the other. The influence on actual diffusion of the degree of similarity between an OOU and an NOU is measured using a number of attributes that are commonly used to describe the operations of mines and mills in the mining industry. These attributes include volume of output, manpower, age of the unit, mineral reserves, labour productivity and whether an operating unit is a mine or mill. In this study, 1985 was used as a base year to select the values for the attributes describing the participating operating units. Volume output was measured in tons of ore extracted for mines and tons of ore processed for mills. The age of the operating unit was determined by identifying the date when the mine or mill extracted or processed its first ton of ore. Mineral reserves were estimated based on the number of producing years for a mine before the ore body was estimated to be exhausted. This was determined by dividing the proven reserves for a given mine by the 1985 rate of extraction. Labour productivity was a measure of tons of ore per production worker per year, either extracted in the case of mines, or processed in the case of mills. These above measures were used to operationalize the following hypothesis:

> HYPOTHESIS 5: The more similar the operations between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by an NOU.

The final hypothesis, to be tested on MTIs that actually diffused, was included to help understand the motivation behind MTI diffusion. Some MTIs may be considered useful only if they improve operations in an economic sense. One interesting question is whether the less tangible benefits of QWL improvement are being diffused as fully. This area of interest is explored by posing the following hypothesis:

> HYPOTHESIS 6: Productivity-improving MTIs (PMTIs) will be actually used by a greater number of NOUs than will Quality of Work Life-improving MTIs (QMTIs).

Although not hypothesized, reasons for or against the use of an MTI were noted and reported. The use of an OOU's MTI may be considered redundant by an NOU because a similar MTI may already have been innovated or the technology involved in an MTI may be already included somewhere in the NOU's production technology. Different vintages (such as successive models of the same equipment) and makes of equipment may avoid problems or make certain opportunities unavailable.

Whether an NOU is satisfied with the approach taken to a problem or opportunity, and why, represents a large residue of factors affecting diffusion. One such factor may be the possible manifestation of the not-made-here syndrome. A person deciding on the usefulness of an MTI may be influenced more by the fact that it came from another place than by the merits of the technology itself. Another aspect of satisfaction which may affect potential use of an MTI is whether the benefits perceived by the NOU are great enough to motivate it to use an MTI. The expense of acquiring an MTI would be assumed only if the costs of acquiring and adapting it were expected to be exceeded by its benefits.

The absence of a) awareness of an MTI, b) adequate satisfaction of a need by an MTI, and/or c) compatibility between OOU and NOU operations may halt or delay the diffusion of MTIs to potential users.

POTENTIAL DIFFUSION OF MTIs

Some MTIs may actually be used by some NOUs. The interesting follow-up question is: if some NOUs can use an MTI, could even more MTIs be used by more NOUs? The potential answer has two parts. First, how many MTIs actually used by an NOU could potentially be used by other NOUs? Second, how many MTIs that were not being used by an NOU, could be used in the future? Determining the potential for diffusion was considered important by the researcher in assessing whether the level of actual diffusion activity reflected the demand for MTIs or whether there were barriers to diffusion, such as poor communication between parts of the firm. If there was no genuine demand for MTIs from other operating units, then MTI diffusion was not a real problem worthy of management attention. If there was a genuine need for MTIs from other properties and no diffusion, then that was an indication of a potential problem to be solved or an opportunity being missed, and should get management attention.

The potential for diffusion may be influenced by some of the same factors that affect actual diffusion. Whether an NOU considers an MTI potentially useful may depend on geographic proximity, management jurisdiction and operating similarity between OOU and NOU. Also of interest was whether NOUs found PMTIs more desirable than QMTIs. The following additional hypotheses were tested:

HYPOTHESIS 7 : The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by the NOU.

HYPOTHESIS 8 : The greater the geographic proximity between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by the NOU.

HYPOTHESIS 9 : The more similar the processes between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by the NOU.

HYPOTHESIS 10 : PMTIs will be perceived as potentially useful to a greater number of NOUs than will QMTIs.

Statistical Testing of the Hypotheses

This section summarizes how the data gathered during this research (described later in this chapter) were organized for each hypothesis, and statistical tests applied to derive the results reported in Chapter 6. Appendix 4 contains details about the mechanics of the statistical tests. Chapters 4 and 5 describe more about the characteristics of

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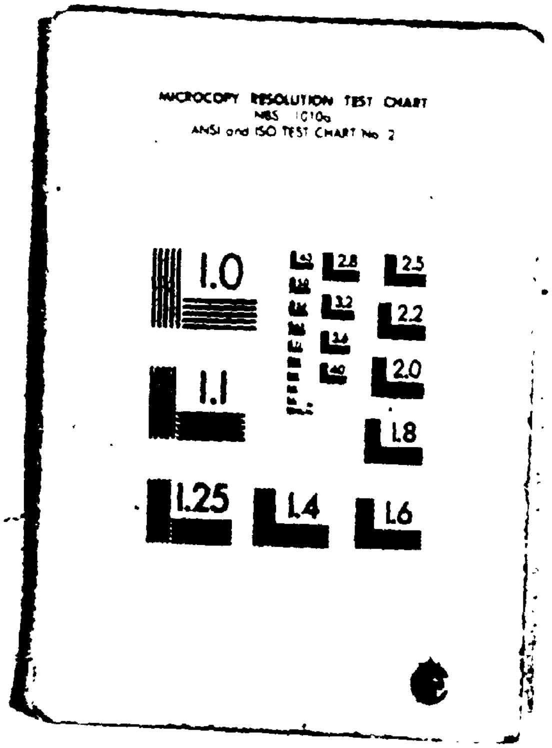

MICROCOPY RESOLUTION TEST CHART
NBS 1010a
ANSI and ISO TEST CHART No. 2
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

the research site and the MTIs that influenced the design of the study.

The statistical analysis of the hypotheses for this research was designed to make the best use of small amounts of nominal data. Some data were in interval and ratio form but could only be used with any validity when combined into nominal groupings. For these major reasons, three common non-parametric statistical tests were used: binomial test, chi square test for two independent samples, and the median test. All are described extensively in Siegal (1956). (1)

As mentioned in Chapter 2, this research adopted the Mohrs and Downs convention of looking at the unit of analysis as the innovation decision made by a given innovator about a given innovation. Translated into the context of this research, each decision by an NOU about whether an MTI was actually used in its operations or not actually used but potentially useful was counted as one observation. The value of these observations wase either "yes" or "no". The influences on whether an NOU would say yes or no to the actual or potential use of an MTI also had their values placed into nominal categories (e.g., high vs low) A number of contingency matrices were constructed, then tested statistically for significant relationships and visually examined for direction. Where possible, the most statistically powerful test was used to test the hypotheses. As the data were collected, the researcher found that the number of MTIs that diffused was not sufficient to justify the use of the chi square and median tests on hypotheses directed specifically at actual diffusion. As a result, the less powerful binomial test was used extensively to test the hypotheses about actual diffusion. The tests of all hypotheses use a 95% level of confidence in determining support or rejection. Table 3.1 summarizes the tests used for each hypothesis. The discussion below summarizes how the the tests were applied.

In Hypothesis 1, the number of observations of actual use of an OOU's MTI by an NOU is compared to the number of observations of no use. The null hypothesis is that there should be no significant difference between the number of observations for the two conditions. There should be close to a 50/50 split of the MTIs between the two. By use of the binomial test, the probability of getting a 50/50 split with the existing data is determined. Using the normal approximation of the binomial for samples greater than 25, a test statistic is derived for this condition. If there was less than a 95% chance of getting a 50/50 split, the null hypothesis was rejected and the alternative hypothesis (research hypothesis) was accepted.

TABLE 3.1 - Summary of Statistical Tests Used For Hypotheses

Hypotheses	Test Used
Hypothesis 1	Binomial Test
Hypothesis 2	Binomial Test
Hypothesis 3	Binomial Test
Hypothesis 4	Binomial Test
Hypothesis 5	Binomial Test
Hypothesis 6	Binomial Test
Hypothesis 7	Chi Square for Two Independent Samples
Hypothesis 8	Chi Square for Two Independent Samples
Hypothesis 9	Median Test
Hypothesis 10	Chi Square

In Hypothesis 2, observations of actual use were split into two groups which differed in that one contained observations of actual use between an OOU and NOU in the same division, and the other between an OOU and NOU of different divisions. Within the research site these divisions were referred to as "groups". The null hypothesis for a binomial test states that there is no significant difference in the number of observations of actual diffusion between OOUs and NOUs that are in the same group as opposed to a different group. The derivation of the test statistic and its significance is the same as in Hypothesis 1.

In Hypothesis 3, the observations of actual use were split into two groups depending on whether the OOU and NOU involved were closer to each other as opposed to more distant. Geographic proximity could have been measured in terms of travel distance, time or by straight line distance between two points. One practical problem of using these methods was in determining whether one of two NOUs was appreciably more distant from an OOU when the difference might be only a few miles compared to many to get to the closer of the two. This problem was dealt with in the research by assigning each operating unit to one of three regions. If an MTI diffused within its region, it was assigned as "close". If an MTI diffused to an NOU outside its region, it was considered "distant". The null hypothesis for this binomial test was that there is no significant difference in the number of observations of actual diffusion between OOUs and NOUs that are close as opposed to distant. The deriving of the test statistic and its significance was the same as in Hypothesis 1.

In Hypothesis 4, observations of actual use were split into two groups depending on whether the OOU and NOU exhibited high similarity as opposed to low similarity. Similarity was measured independently by five attributes. The smaller the difference between the value for an attribute of an NOU compared to an OOU, the greater the similarity between the two operating units. The median value of these differences for all the possible pairings of NOU with OOU for a given attribute, was used as a decision rule in placing observations in either the high or low similarity group. The five attributes tested were Output Volume, Manpower, Labour Productivity, Mineral Reserves and the Age of the Operating Unit. The null hypothesis for a binomial test applied to each attribute was: there is no significant difference in the number of observations of actual diffusion between OOUs and NOUs that exhibit high similarity as opposed to low similarity.

In Hypothesis 5, observations of actual use were split into two groups depending on whether the MTI was more recent or less recent. The median value of the age distribution of the MTIs sampled from the OOUs in this research was used as a decision rule in putting observations in either the more or less recent group. The distribution of ages and its median are presented in Chapter 5, Figure 5.1. The median age was 2 years. The null hypothesis for a binomial test was: there is no significant difference in the number of observations of actual diffusion between OOUs and NOUs that are more as opposed to less recent.

In Hypothesis 6, observations of actual use are split into two groups depending on whether the MTI was a PMTI or a QMTI. The expected portion of observations for each group was adjusted to reflect the difference between the number of PMTIs and QMTIs in the sample. The null hypothesis for a binomial test was: there is no significant difference in the number of observations of MTIs that actually diffused that are more as opposed to less recent.

For the hypotheses about the potential use of an OOU's MTI by an NOU, the more powerful chi square and median tests could be used due to the greater number of observations. The statistical tests for these hypotheses involved assigning observations to a number of two by two contingency tables. Observations were divided first into two groups. One contained all observations where an NOU indicated that it could potentially use an OOU's MTI. The second contained all observations where an NOU indicated that it could not potentially use an OOU's MTI. These two groups were compared as to how they discriminated between categories for the influences hypothesised. The fundamental difference between the use of a chi square for two independent samples and a median test is that the median test uses the median value of a variable to discriminate, as opposed to an arbitrary assignment of observations into one group or another.

In Hypothesis 7, observations of potential use and no potential use were cross-tabulated by whether they involved an NOU or an OOU from the same division or different divisions. The same convention used in Hypothesis 2 to place observations was used in this hypothesis. The null hypothesis was: there is no difference between the observations of potential use and observations of no potential use in proportion that will be close versus distant.

In Hypothesis 8, observations of potential use and no potential use were cross-tabulated by whether they involved an NOU or an OOU from the same geographic region, an adjacent geographic region or a distant geographic region. The use of the chi square test for this hypothesis affords the opportunity to take advantage of the natural clustering of the operating units into three collinear clusters. A map is provided in Chapter 4, Figure 4.1, illustating this clustering. The null hypothesis was: there is no difference between the observations of potential use and observations of no potential use in the proportions of observations that are in the same, adjacent and distant geographic regions.

In Hypothesis 9, observations of potential use and no potential use are cross-tabulted by whether the OOU and NOU exhibit high similarity as opposed to low similarity, as measured independently by five attributes. As in Hypothesis 4, the smaller the difference between the value for an attribute of an NOU compared to that of an OOU, the greater the similarity between the two operating units. The median value of these differences for all the possible pairings of NOUs with OOUs for a given attribute was used as a decision rule in putting observations in either the high or low similarity group. The five attributes tested were: Output Volume, Manpower, Labour Productivity, Mineral Reserves and the Age of the Operating Unit. The null hypothesis was: there is no difference between the observations of potential use and observations of no potential use in the proportions of each that are assigned to high or low similarity for an attribute measure.

In Hypothesis 10 , observations of potential use and no potential use were cross-tabulated by whether they involved PMTIs or QMTIs. The null hypothesis was: there is no difference between the observations of potential use and observations of no potential use in the proportions of observations that were PMTIs and QMTIs.

Research Methodology

The data collection methods used in this thesis had to perform well on two dimensions. First, an audit of the research site had to capture accurately MTI activity within the research site. Second, the results of that audit and the response to it had to be communicated accurately between researcher and the participants at the research site. Given the exploratory nature of the research, it was desirable for the research methods to be flexible enough so that the researcher could take advantage of opportunities during the data collection to include unanticipated observations about the nature of MTI diffusion. This section describes the research methods chosen for data collection and the major details and issues considered in their selection.

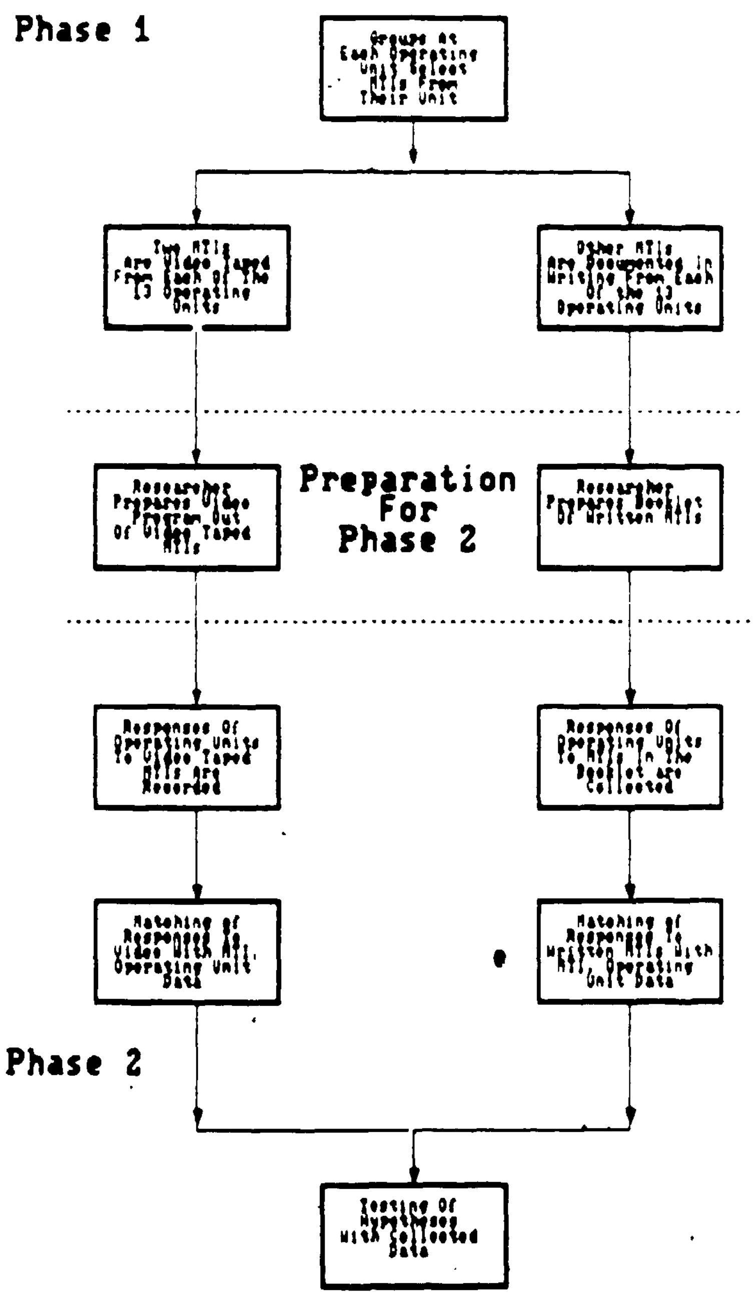
Overview of Data Collection

A combination of interview and questionnaire survey techniques, supplemented by archival data was used. Some MTIs were documented using both video tape and written descriptions. The documentation process involved the researcher in field visits to 13 operating units within the research site. Of these, seven were mines and six were mills. The researcher visited each operating unit twice The first visit to all operating units was called Phase 1 and involved selecting and documenting the MTIs. The second visit was to collect responses to some of the selected and documented MTIs and was called Phase 2. Participant observation by the researcher was an effective method for checking the reliability of the documentation and controlling for possible threats to validity. Responses to the video taped MTIs by NOUs were also collected by the researcher during on-site visits. Responses to the written descriptions of MTIs by NOUs were collected by mail and checked by telephone. Figure 3.1 contains a process flow diagram of how the data for the thesis were collected. A description of the events in Figure 3.1 follows.

PHASE 1 - SELECTING THE MTIs

Each participating operating unit had a representative group of employees which prepared a list of successful MTIs that had been experienced over the previous five years. This group was also used where possible in PHASE 2, when responding to the collected MTIs. The group were asked to create a list of new process changes implemented in their operating unit that conformed to the definition of an MTI mentioned earlier in Chapter 2. The most successful Productivity Improving MTI (PMTI) and Quality of Working Life

FIGURE 3.1 - Data Collection Process



Improving MTI (QMTI), used within an operating unit were selected by this group. Both MTIs were recorded and explained briefly on a video taped segment of approximately 2 minutes long. The remaining items on each group's list of process changes, which qualified as MTIs, were documented in a written description. This description covered the same basic information that was on the video segments and in the back up documentation for those segments.

PHASE 2 - RESPONDING TO THE COLLECTED MTIs

At a meeting with the researcher, each operating unit group was shown the video taped segments from the other operating units. The order of presentation of the segments was randomized prior to the meeting. The groups were asked if a similar MTI was in use in their operating unit. If the answer was yes, the particulars of the MTI's use at that operating unit were requested. If no, the reasons for not adopting were collected. Each member was asked if he or she would consider potentially using an MTI, if it was not already in use in their operating unit. Discussion on the topic was observed and recorded.

Each operating unit group was sent a copy of the booklet of written descriptions of the MTIs that were not video taped. On a questionnaire attached to the back of the booklet, each operating unit group was asked if a similar MTI was in use in their operating unit. The questionnaire contained questions similar to those asked by the researcher in the meetings to view the video tapes. If the answer was yes, the particulars of the MTI's use at that operating unit were requested. If no, the reasons for not adopting were collected. Each member was asked if he or she would consider potentially using an MTI, if it was not already in use in their operating unit.

The collected results from both methods of survey were matched to archival data collected about the attributes of the MTIs and the attributes of the operating units. Each response by an NOU to an OOU's MTI was counted as one observation. This data was stored in computer data files for statistical hypothesis testing using a computer statistics package.

The video taped MTIs and resulting interview survey preceded the booklet of written descriptions of MTIs. The preliminary results of the operating unit groups responding to the video taped MTIs were used to prepare the questionnaire for the back of the booklet. The familiarity and interest created by the video taped MTIs was used to administer the questionnaire with less confusion and with a higher likelihood of cooperation. Examples of the data collection forms used to document the MTIs for both video taping and the booklet are provided in Appendix 3. Also included in Appendix 3 is an example of the the questionnaire items used for the MTIs in writing.

Selection Of Operating Unit Groups

Each operating unit manager was asked prior to the researcher s arrival to select a group of three or more employees, including themselves, to participate in both phases. Group members were to be asked to participate voluntarily but the operating managers were to be selective in whom they asked. A group member was to be familiar with the operating unit, having accumulated at least a year of seniority. Operating units were asked to supply representation from supervisors, tradesmen and labourers as well as engineers and technical staff. All participants were asked to be proficient in English. In instances where English/French translation was required for membership in the groups, assistance was found. Each participant in a group, whether in Phase 1 or Phase 2, was asked to fill out a personal history form. A copy of the form is in Appendix 3 and a descriptive statistical summary of the composition of the individuals participating in the groups is presented in Chapter 4.

Selection Of MTIs

Prior to the researcher's arrival on site, the operating unit managers were asked to question their employees about innovative technology that fit the definition of an MTI used in this research. Each group sat down with the researcher to select the two representative MTIs for video taping from their prepared list. Each item on the list was discussed and where possible the researcher was shown the physical evidence. Each group was prompted by the researcher for further innovations that might qualify as MTIs. Intense interaction with the personnel of the operating units was necessary in order to exhaust the records and memory of participants and elicit a significant representative sample of the unit's MTI activity.

Data Collection Instruments

This thesis used some unique methods to document and communicate MTIs. The use of video tape as an instrument of data collection represents a methodological innovation which could be diffused to other management research. In this research, the use of video tape presented the researcher with an opportunity to be more effective in involving respondents and communicating clearly in a time efficient manner.

VIDEO TAPING OF MTIs

Two MTIs from each operating unit, one PMTI and one QMTI, were selected by the groups and documented by the researcher. The group was then asked to select a member or non-member familiar with the MTI to act as narrator and provide the voice-over description for the video picture. The researcher was taken to the site of the MTI by a guide familiar with it. This person was often the narrator. Approximately two minutes of color footage was shot of each MTI in operation. The taping direction endeavoured to eliminate as many cues as possible that would suggest the identity of the operating unit. Where possible, people were shown interfacing with a particular MTI.

The narration was dubbed onto the video picture immediately after the taping and on site where ever possible. The narration for each segment is transcribed in Appendix 1. The narrator was given some coaching by the researcher in order to standardize the format and improve the quality of the narration. The narrator was encouraged to use the technical jargon and instruction style that he or she might use when explaining the MTI to a fellow employee. A standardized format was designed to govern the presentation of the content. First, the MTI was introduced by its commonly used name. Then the problem or opportunity the MTI was meant to address was stated. Significant technical details about how the MTI worked or was used, were related. Finally, benefits and problems associated with the MTI were summarized.

A pre-test of the video tape technique was performed at The University of Western Ontario prior to the field study. Two operating units of the printing department, both distinct profit centers, were asked to select an MTI innovation, following the guidelines and procedures already discussed. Each was video taped, then shown to the other operating unit. Responses were recorded in a manner similar to that to be used out in the field. The results of the test emphasized the importance of using a well coached narrator who sounded credible. It was also considered important to show people interfacing with the MTI in order to give a sense of scale and maintain viewer interest. Both these suggestions improved the video presentation of the MTIs.

DESCRIBING OTHER MTIs IN WRITING

MTIs that were not selected for presentation in the video tape were used in the booklet describing MTIs in writing. The descriptions were completed by group members under the supervision of the researcher. Where possible, pictures and diagrams were used to supplement the written descriptions. The standardized format for presenting the content was similar to the video taped segments. Based on the experience gained from compiling and presenting the video taped segments, the practice of not identifying the operating unit was relaxed. Some people wanted to know the OOU and were suspicious about the motives for the research if they did not know. A contact for further information about the MTI was given for parties interested in following up on an MTI. The 43 MTI in writing were collected in a 58-page spiral bound book divided into two sections, one for mining MTIs and one for mill MTIs.

Prior to the release of the booklet, the results of the video taped presentations to all operating units had been received. The separation between mill and mine MTIs was abundantly clear from an analysis of the results. Mills would not consider seriously the actual or potential use of a mine MTI and vice versa. Therefore, mill groups were instructed to concentrate on the mill MTIs and mine groups on the mine MTIs. Mill and mine MTIs were separated in the booklet. A questionnaire was placed at the back of the booklet and referred to by a introduction at the front. The questionnaire asked about potential and actual use of the enclosed MTIs by the NOU. The complete booklet of MTIs, minus the questionnaire, is presented in Appendix 2. The questionnaire is in Appendix 3.

Responding to the Video Taped MTIs

Group members were asked to allocate a three hour period of their working day on a convenient date to view and discuss the 28 MTIs from other operating units. These sessions took place on site at the operating units. Each participant was given a series of response sheets, one for each MTI. When a video taped segment was shown, the participants were asked to record individually their answer to whether the MTI was actually or potentially of use to their operating unit and then briefly explain their answer. Next, the MTI was discussed by the whole group to arrive at a consensus about the same basic questions and reasons. The researcher recorded the consensus and comments.. After the session, the response sheets were collected with the group member's name attached.

The groups were instructed by the researcher to consider the potential and actual utility of an MTI only in the context of their own operating unit. If the groups required more information, the supporting documentation was consulted. The collection of individual response sheets was used as a control to ensure that there was no silent dissent by individual group members, and to test the strength of the consensus. Occasionally there were dissenting opinions within a group about an MTI. Conflicts about the actual or potential use of an MTI were resolved by group discussion. Some people had no opinion about an MTI and thus remained silent about what they thought about an MTI. They tended to go along with any emerging consensus in the group. Constraints on people's time and concentration were accommodated in the methodology. The interview methodology just detailed was effective in getting the required content from numerous people in a short time period. The interview techniques were tested to some extent during the University of Western Ontario pre-test of the video techniques.

Responding to the Written Descriptions of MTIs

A questionnaire attached to the back of the booklet of described MTIs was used to record the reponses of NOUs to the abstracts. The questionnaire benefited from the results of the video presentation. The content of the response to the video was analyzed and the categories explaining why an MTI was potentially of use were derived from the results.

The booklets with questionnaires and instructions for their implementation were mailed to specific individuals at the operating units charged with the responsibility for getting the completed questionnaires returned to the researcher. Records were kept of who filled out the questionnaires and all others participating in the exercise. Twelve out of thirteen operating units responded. One operating unit declined to respond due to time pressures on its personnel. People filling out the questionnaires had access to the researcher by a telephone which was monitored 24 hours a day by an answering machine. The researcher made periodic checkups on the operating units by telephone to identify problems, answer queries and check progress.

Controlling The Research Design

The research was designed to control for possible threats to internal validity which might be posed by:

1) A small non-representative sample of MTIs that was biased and statistically inconclusive.
2) Instrumentality or halo effects associated with using one survey technique exclusively.
3) Lack of reliability in participant responses.
4) Common diffusion research biases.

Sampling MTI

Convenience sampling has been the norm rather the exception in the technological innovation and diffusion literature. The number of technological innovations and the number of firms sampled for innovations varied. A common problem with diffusion research was that the true potential adopter population was never known with certainty. This was due partly to the cross-sectional rather than longitudinal time series design of these studies. This was not a major problem with the proposed research since the researcher tried to document all MTIs, in some form, that people could reliably remember.

Small sample non-parametric tests (binomial and chi square median test) were used to test most of the hypotheses. The statistical tests were not used unless the number of observations being tested was sufficient to meet the commonly accepted standards of usage for a given test.

Thirty MTIs were video taped and 43 were described in writing. The combination of the two methods facilitated the collection of a larger sample and improved the ability during data analysis to cross-tabulate the data, as suggested in the research hypotheses (e.g., QMTI or PMTI by diffused or not diffused). The number of MTIs sampled and the sampling method were affected by the amount of time that participants had available at the various operating units. Video taping tended to take longer than documenting MTIs in writing.

Instrumentality and Halo Effects

The use of the video survey technique presented both opportunities and potential problems. In a clinical pre-test of the methodology at The University of Western Ontario, video taping was found to be an effective and efficient way to communicate information of a technical nature so that respondents could make informed replies in a short time. The technique could potentially induce a selection bias such that OOUs might concentrate only on photogenic MTIs. It was difficult to determine whether and how much a respondent's answer to a question was influenced by the medium used to document the MTI as opposed to the actual MTI itself.

These concerns were partially controlled for by the use of a more traditional written questionnaire survey instrument for documenting some MTIs and the presence of the researcher during the selection of the MTIs. The differences between the responses for video taped MTIs and written MTIs are mentioned in Chapter 6. The results raise interesting questions about the importance of the medium used in the adoption decision to convey an innovation to a potential user.

Reliability of Response

One of the major problems with questionnaire research is that people may interpret the question differently or not answer the question at all. The involvement of the researcher in all phases of the responses to the video taped MTIs and close supervision of the questionnaire about the MTIs described in writing, ensured both clarity and consistency. Early field work in Phase 1 involved educating participants in the operating unit groups about the importance of accurate responses to the questioning without unduly biasing future responses. All questions were worded in language familiar to Noranda employees.

In choosing the number of MTIs to sample, respondent fatigue was considered a significant factor. Accurately describing an MTI and documenting its history was time-consuming for both the operating unit personnel and the researcher. The fatigue associated with viewing too many video taped segments or reading too many descriptive paragraphs was an important factor in limiting the number of the MTIs sampled.

Other Potential Biases

PRO - INNOVATION BIAS

Pro-innovation bias is the common assumption that an innovation should be diffused and adopted by all potential adopters very quickly. Therefore, diffusion researchers tend to overlook why innovations do not diffuse and the anti-innovation tendencies of potential adopters. Diffusion researchers have been known to pick, or allow to be picked, those innovations that they found personally attractive. This bias was controlled for by having operating units pick their own MTIs. Operating unit personnel were reminded that MTIs should only be considered successful in the context of their own operating unit.

ADOPTER - BLAME BIAS

There is a tendency to "blame" the potential adopter as an individual for not adopting an innovation, rather than look for reasons attributable to the MTI or the operating unit. The equal and thorough treatment of all participating operating units and MTIs in their documentation controlled somewhat for this bias.

RECALL PROBLEM

The more distant an innovation's date of first use, the more difficult for people to remember details. What is frequently recalled is at best, selective. Being small events, MTIs tend to be forgotten by those in the operating unit who are not directly involved or affected. This problem was controlled for by the use of archival data such as invoices and engineering drawings which provided exact dates and dollars. MTIs considered for the proposed research were less than five years old as of October 1985. In addition, the use of groups at each operating unit rather than a few key contacts provided a broader base of available information about an MTI and a means of cross referencing individual responses.

External Validity In Research Site Selection

The use of Noranda Ltd. as a research site does not preclude the findings of the proposed research from being generalized to other firms. As a multiple operating unit, primary resource industry firm, Noranda was similar to other firms in the Canadian economy in industries such as mining, forestry and petroleum. Many firms are in competitive situations where minor process innovation is important in keeping their various operations profitable. Other industrial sectors, such as manufacturing, have firms similar to Noranda in that they too have multiple operating units which may have similar technologies.

Comments and Conclusions

This chapter presents the hypotheses, the means of testing them, and the methods used to collect the data needed for this exploratory research into the diffusion of minor innovation within firms. The hypotheses tested in the research were preliminary attempts to rigorously study some aspects of the area. The use of a field study, adopting the use of innovative data collection instruments such as video tape, provides a richness of information for testing by formal hypotheses and supplemented with descriptive analysis. The flexibility of the research methods was an important feature of the research, given the lack of clear and well accepted theory available from prior work in the study of innovation to guide the conduct of the research.

References

1) S. Seigel, Nonparametric Statistics For The Behavioral Sciences (Toronto: McGraw Hill, 1956).

CHAPTER 4

THE RESEARCH SITE

Noranda Corporation and the Canadian mineral industry were struggling for survival in the 1980s. The Canadian mineral industry included a number of Canada's biggest and oldest companies, each with thousands of employees and multiple facilities spread across Canada. Increased international competition, oversupply and soft demand for various mineral commodities had driven prices downward. At the same time, government and unions were continuing to press for more tax revenues from natural resources, tighter environmental controls and improved quality of working life. Many firms in the mineral industry during this period had successfully adapted to these pressures, at the same time, reducing costs to or below world prices. Cost reductions were attributed to downsizing and productivity improvement. One important initiative a number of firms took to facilitate cost reduction was to encourage employees to be more innovative in improving all aspects of production.

This chapter contains an overview of the minerals industry in 1985, and specifically, of those firms commonly referred to as "mining companies" involved in the extraction and milling of ferrous and non-ferrous base metals. An overview of Noranda is presented, concentrating on the mining and milling operations participating in this research. Some of the attributes of the operating units used in the hypotheses, presented in Chapter 3, are operationalized. Finally, the potential for generalizing the findings from the research site to other firms in the mineral industry, primary resource firms and other firms in the Canadian economy, is briefly discussed.

The Canadian Mining Industry

The mineral industry achieved output valued at $45 billion in 1985 from four sectors: mineral fuels, structural materials, non-metallics and metallics.(1) Mineral fuels, including oil and coal production and refining, accounted for 70.1% of this total. Structural materials, including stone and gravel, accounted for 4.4%. Non-metallics such as salt accounted for 5.4 %. Metallics, commonly referred to as base metals, accounted for $8.5 billion, or 19%. Most sectors in the mineral industry in the years 1980 - 85 experienced sluggish performance as compared to the 1970's, with the exception of mineral fuels. All sectors in 1985 were under pressure to reduce costs in order to react to prices and demand. The preferred strategy for cost reduction was to improve labour productivity to reduce manpower requirements and capital productivity by the introduction of new, more efficient equipment and methods. The base metal sector of the mineral industry was acutely affected by poor economic conditions. It was in this sector that Noranda corporation had a large part of its holdings, including those used in this research.

Mining in Canada

In Canada, in 1985, there were an estimated 113 metal-producing mines.(2) Approximately 18 different metals were extracted and processed. In order of rated production value, the top four metals in 1985, iron ore, zinc, copper, and gold, accounted for 64.5% of all metal production by value. Metals production directly employed approximately 50,200 Canadians across the nation.

Production from mining companies in Canada, in the 1980's, made up between 3% and 4% of Gross National Product (GNP). This figure included both metallic and non-metallic operations.(3) Crude and processed metal exports accounted for more than 10% of Canada's total export earnings in 1985, with revenues estimated at more than $9 billion.(4) In order of greatest to least earned export revenues, these metals were gold, iron ore, copper, nickel, zinc, silver, uranium, platinum, lead and molybdenum. Canada was the world's leading producer of nickel, zinc and uranium in 1985. Specific regions of Canada such as northern Ontario and Quebec were dependent on mining for employment and as a base for other local industry.

The top ten mining companies in Canada, in 1985, were all producers of base metals. Table 4.1 shows all ten companies as listed by the Financial Post 500 ranked on the value of production sold in 1985.(5) The number of properties in production in 1985 was estimated for each company from the Canadian Mining Handbook 1985.(6) A property was defined as containing one or more mines and/or mills which were geographically separated from other mines and mills. Some properties had temporarily suspended operations in 1985 but were counted in Table 4.1. Noranda in 1985 was the largest domestic extractor and processor of metals. Alcan extracted most of its metals offshore and shipped them to Canada for refining. For example, Alcan extracted bauxite in Jamaica and exported it to Canada to be refined into aluminum. Noranda had the most geographically dispersed operations in Canada of all the mining companies, with properties from British Columbia to New Brunswick. Five of the top ten mining companies had more than one property separated from others by provincial boundaries.

TABLE 4.1 - Top Ten Mining Companies In Canada and Their Properties in 1985

Rank	Company	Value of Production (000)	Properties Producing In Canada
1.	Alcan Aluminium	$ 7,806,214	0
2.	Noranda	3,436,862	23
3.	Inco	2,034,148	19
4.	Rio Algoma	1,226,924	4
5.	Falconbridge	890,247	7
6.	Denison Mines	736,608	3
7.	Sherritt Gordon Mines	445,374	2
8.	Quebec Iron and Titanium	426,000	1
9.	Placer Development	422,273	2
10.	Hudson Bay Mining	280,748	11

NOTE: Ranking based upon the value of production.

SOURCE: Adapted from:

1) The Financial Post 500, (Summer 1986): p. 98.

2) The Northern Miner, Canadian Mines Handbook 1984 -85 (Toronto: Northern Miner Press Limited, June 1984).

Recent Performance of the Mining Industry

The 1980's have been characterized by falling metal prices, oversupply on international markets and weak demand by traditional users of metals. After experiencing a cyclical boom in 1979 and 1980 with high prices and full utilization of existing capacity, the mining industry felt the full and unexpected effects of a world-wide recession in 1981. As demand dropped for metal products, foreign countries scrambled for foreign exchange by dumping metals on the oversupplied market. As a result, prices fell. Copper prices, for example, fell 33% from 102.4 cents per pound in 1980 to 68.2 cents in 1984. (7) Many mines suspended operations in Canada. Those that stayed open tended to be operations with rich, high grade orebodies and newer, more efficient operations which kept operating costs competitive both domestically and internationally.

Coming out of the recession in 1983, world metal prices had improved in some commodities such as zinc and gold. Oversupply continued to be a major depressant of the price of some commodities in 1985. For example, countries such as Chile were dumping their copper on the world metal markets. Metal users in 1985 had been slow to build up inventories after the shock of recession; therefore demand for metals had continued to be weak. The appreciation of the Canadian dollar relative to European currency during 1980-85 had also suppressed demand from that region and other parts of the world. The forecast for the economy of Canada and the world for the late 1980's was a slow improvement in demand and thus stabilization and improvement in metal prices.(8)

From 1980 to 1985, mining companies had survived by drastic cost-cutting and diversification or divestment. Industry analysts generally agreed that during the 1970's, mining companies carried a sizable layer of "fat" in their operations accrued from decades of healthy and stable earnings. The fat was in the form of surplus employees, overly generous wage settlements and the maintenance of marginal properties. The first action taken by many firms in the 1980's, to reduce costs and streamline operations was the massive reduction in the number of blue and white collar employees. At INCO, the world's largest nickel producer, the total number of employees worldwide was reduced 39% between 1980 and 1985.(9) At the same time, major new technology such as remote-controlled scoop trams and continuous mining techniques was introduced to reduce headcounts, improve safety and increase productivity in some mines. Some marginal properties were closed indefinitely, awaiting improvements in metal prices or the economics of the technology used in the mines. Projects to mine lucrative metals, such as gold, were given top priority in order to supply much needed cash flow earlier. The net result in 1985 was that most metal producers had lower operating costs per ton than they had in 1980. This was in spite of continuing demands for higher wages, improvements in working conditions and escalating costs in activities such as environmental control and the transportation of metals to market.

The Metal Production Process

The development of a mining property is a long and expensive undertaking. Millions of dollars are spent finding and exploring the potential of an orebody. Only one in a thousand exploration prospects ever becomes a producing mine.(6) Starting from when an orebody is considered economically viable, development begins along a path that will make the resulting mining and milling operations unique to that property. There is no one standard design for the layout of the mines and mills planned for a property. Each property has its own unique combination of mineral content, distribution of minerals in the rock formation and grade considerations. Minerals are held in rock formations that vary between properties. Transportation costs vary between properties, depending on the relative position of mines, mills and smelters. These factors and others determine the economics of a property. Return on investment is realized over the long term when the custom-made plans for a property's development come to fruition and are found in reality to be appropriate for the supply and demand situation in the metals markets.

The production process for a mining property involves three major components. First, metal-bearing ore is extracted either from open pits or underground. The ore is transported either to a mill on the property or on another property where the metal is separated from the waste rock and concentrated into a powder. The concentrate is then transported from the mill to a smelter or refinery located either on the property or at another property, where the metal-bearing concentrate is further upgraded to a purity whereby the metal can be used for metal fabrication. This study focuses on the mining and milling operations, excluding the smelting and refining operations. These latter facilities were not accessible for study at the time of the research. All the mines in this research are underground except for the Mines Gallen open pit, which in 1985 functioned as a part of the Horne mining department.

MINING

A common expression in the mining industry is that no two mines are the same. Some mines are open pit, others are underground. An open pit mine involves blasting a series of concentric steps into the earth. The ore is scooped up and carried out of the pit by large trucks. Underground mines can be operated as the continuation of the recovery of ore begun in an open pit mine. Most underground mines consist of a number of tunnels at different levels radiating from a central shaft and/or access tunnel, consisting of ramps criss-crossing upwards to the surface. At the different levels, ore is recovered in work areas called stopes. This involves drilling holes into the ore-bearing rock in various patterns which are then packed with explosives. Ore is blasted from the work face to lie as rubble, which is then handled by scoop trams. The ore is loaded into narrow gauge railway cars or rubber-tired vehicles. They are used to transport the ore either to a hoist that ascends the shaft or to the access ramp to be trucked to the surface.

A mine is both highly labour-intensive and capital-intensive. Up to 50 % of operating costs in a mine can be attributed to labour. The installation, replacement and maintenance of plant and equipment are a constant drain on capital. At some properties more people may be employed in the plant department which is responsible for these functions than in the actual mining of the ore. The high costs of maintenance reflect the wear and tear of the operating situation on people and equipment. Often, both have to be employed 24 hours, three shifts a day, in order to produce a reasonable return on investment.

The underground environment for men and machines is expensive to maintain. Fresh air must be drawn to work areas as far as a mile underground. Utilities such as light, water and sewage disposal must be provided. Every foot of tunnel must be secured from falling rock and unplanned destruction during blasting. Dust and potentially toxic or flammable gases must be controlled. Men, machines and ore must be hauled to the surface by energy-consuming heavy equipment. Machinery such as drills and vehicles has a short life span due to the rough handling and hard materials it is in contact with daily. Continuous maintenance of expensive heavy equipment is unavoidable.

Most mines have a superintendent as the operating unit's most senior manager. The superintendent usually has a chief engineer and a staff of engineers, geologists and draftsmen reporting to him. Blue collar workers are directly supervised on each shift by a mine captain who is reported to by various foremen or labour bosses. Most positions for blue collar workers such as driller and scoop tram operator are secured by a certification process involving training and examination. Some maintenance workers such as electricians and mechanics may be under the separate authority of a maintenance or heavy equipment foreman. Some properties have maintenance people for mines and mills under the supervision of a third major department called plant, which has its own superintendent. Other personnel attached to a mining operating unit might be a safety supervisor, first aid officer, hoist operators and a number of clerical workers.

MILLING

The mill, also commonly called the concentrator, is fed directly from the mine by large conveyor belts running between the mine shaft or access ramp and the mill. Some mines have conveyors that extend down to levels underground. Some mines transport the ore to mills by truck or train. Frequently, stockpiles of ore are kept in orebins which act as decoupling inventories between mining and milling processes. The stockpiling of low grade ore is a common practice which allows the mill to process more profitable high grade ores when prices are low, then go back and process low grade ores when the metal prices are higher.

The technology involved in milling non-ferrous ore of the type mined at Noranda properties is different than that used to recover ore from a mine. Metal-bearing ore is first crushed into a fine powder. This powder is mixed with air, water and various chemicals called "flotation reagents" and placed in a series of large agitating vats. The reagents cause metallic minerals to float to the top where they can be skimmed off. The net result is that valuable minerals are retained and undesirable materials are removed. The dry metal mineral powder shipped from the mill to the smelter is anywhere from 10 to 50 times more concentrated in the desired metal than the ore that was input into the mill from the mine(s). Waste water, chemical and rock is disposed of in large tailings areas on the property. Water is treated for reuse at most properties.

The milling of ore and the recovery of concentrate is a process that requires constant monitoring. The slurry of floating minerals undergoing separation in the mill vats must be kept at a constant of temperature and chemical composition in order for the process to be efficient. Equipment and the results of assays taken of material passing through the mill are monitored hourly. Unlike the mine, the mill cannot easily decouple parts of the production process to deal with problems. Maintenance is an important part of ensuring the continuous operation of the mill.

Many of the chemicals used as reagents are caustic to machinery and poisonous to humans unless handled carefully. Although generally regarded as cleaner and safer than mines, mills can be dusty and noisy places to work.

The mill usually has a superintendent who is reported to directly by the chief metallurgist and his staff of metallurgists, geologists and laboratory technicians. Foremen at the average mill would be responsible for instrumentation, environmental control, and the three shifts of blue collar, hourly rated workers. Hourly rated workers do a variety of manual jobs such as adjusting, checking and cleaning equipment. A mill may have a number of clerical workers.

Improving Productivity In the Mining Industry Through Innovation

> Interest rates, wages, wage levels and energy costs are largely beyond the control of mining companies, as is the unit price received for minerals. Therefore, only by reducing the amount of capital and/or labour employed per unit of output can rising costs be held in line with steady prices. This is the role of productivity improvement. (11)

Many of the major mining companies were pursuing productivity improvement through technological innovation in 1985. Technological innovation was occurring in two ways.

First, major innovations in the mining and milling operations were being introduced to radically change the production process. These were the result of major research and development programs. Second, minor innovations were introduced as a result of employee involvement in cost reduction and productivity improvement efforts.

The deteriorating debt/equity ratios of firms in the Canadian mining industry discouraged major investment in plant and equipment. In the early 1980's, major capital projects were cancelled or put on hold. Some firms, realizing that new technology represented a unique means for Canadian mining to gain a competitive advantage, developed major new mining processes. One highly publicized example was the development of vertical retreat mining by INCO. The utilization of this and other associated innovations had the potential to reduce costs significantly in the average mine. INCO reported an 80% reduction in costs by the adoption of vertical retreat methods in conjunction with other innovations. (12) Realizing the importance of developing major new mining and milling technology, and the large investment required, four of the largest Canadian mining companies, namely INCO, Noranda, Falconbridge and Kidd Creek launched a joint research effort in 1984 called the Hrdk Mining Research Corporation. The federal government had funded major investment in new technology through bodies such as the Canadian Centre for Mineral and Energy Technology (CANMET). The combined investment of industry plus government money and resources into new technology was viewed by many in the industry as important to the future of mining in Canada.

Technological innovation and productivity improvement were linked with greater employee involvement in some companies. In order to get employee cooperation and involvement in technological changes, quality of working life considerations of personal interest to employees were also investigated. Management commitment to lowering the costs of injured and unhealthy workers had also been a motivating force in implementing operating improvements. Employee involvement has been observed by Richardson to be practiced by various Canadian mining firms in one of four forms. (13) First, QWL programs were introduced with productivity as the hoped-for by-product. Second, employee effectiveness programs were launched to improve worker participation. Third, cost reduction programs featured employee involvement, without tangible financial rewards to employees for their efforts. Finally, there were cost reduction programs with employee gain-sharing of the revenues and savings from efforts attributed to employees. These efforts tended to demand more employee involvement and management commitment than the older suggestion box schemes of the past. The reported results from these programs have been mixed. Success depended to a large extent on how these programs were implemented and maintained. If there was sustained commitment on the part of management in maintaining these programs, they had a higher likelihood of success. The employee innovations that came out of these programs usually involved minor technical changes to operations that contributed to the overall drive company-wide to reduce costs.

Noranda Corporation

Overview and History of Noranda Inc.

Noranda and its associated companies in 1985 were engaged in four major areas of business: mining and metallurgy, manufacturing, forest products and oil and gas. In 1985 the company was 96% Canadian-owned. The head office was in Toronto. In 1984, the company and its subsidiaries changed their name from "Noranda Mines Limited" to "Noranda". The various other companies in which Noranda had major shareholdings were called "associated" companies. Noranda, with its associated companies, produced copper, molybdenum, gold, silver and lead and was the world's largest producer of zinc in 1985. Noranda smelted and refined most of its own mine production as well as, on a custom basis, concentrates and other minerals produced by unrelated mining companies. Manufacturing operations in Canada primarily consisted of processing metal into wire, cable, sheet and tube products. In the United States, manufacturing operations consisted of primary aluminum production, fabrication of aluminum building products, production of aluminum sheet and foil products and the extrusion of wire and cable. Noranda's associated companies in 1985 were the largest producers of forest products in Canada, producing lumber, plywood, waferboard, pulp, paper, newsprint and containerboard. These companies included MacMillan Bloedel, Maclaren, Fraser and Northwood Pulp Inc.. Noranda and its associated companies, in 1985, were actively exploring for minerals in Canada, the United States and further abroad and for oil and natural gas in western Canada and the United States.(14)

Table 4.2 shows the relative size of the four parts of Noranda in terms of net assets in 1984, and the number of employees in 1985. In Canada, Noranda's mining operations employed the largest portion of people, as well as managing Noranda's largest stock of assets.(15)

Noranda was originally formed in 1922 to develop the rich copper and gold orebody in Noranda, Quebec. The first

TABLE 4.2 - Net Assets, and Employees for Noranda's Major Areas of Business

Major Area of Business	Net Assets (millions)	Employees
Mining and Metallurgy	$ 2,222	13,100
Oil and Gas	477	...
Manufacturing	1,719	9,700
Forest Products	1,726	22,700

SOURCE: Noranda Corporation

Horne mine came on stream in 1927, followed soon after by a concentrator operation to process the mine's copper and gold-bearing ores. With the help of two other partners, the company took its first step in building a vertically integrated corporation by starting a copper refining operation in Montreal in 1930. At the same time, the partnership purchased the interests of Canada Wire in order to secure an end market for the refined copper.

During the 1930's, Noranda Mines diversified by buying interests in a number of other mines, including three gold mines in the Timmins, Ontario region. From this period on into the 1960's, Noranda Mines grew by diversifying into the mining industry in Canada. It also bought interests in international mining properties and diversified into other metals such as zinc and lead. In the 1950's it developed new mines such as the copper mine and mill called Geco in northern Ontario. Noranda's strategy for growth had been to buy controlling interest in properties it was interested in then supply management expertise to the acquisition. Where a lucrative ore body had been indicated by Noranda's exploration operations or those of other firms, Noranda have alone or in partnership developed the property.

In the 1970's, Noranda enlarged its holdings in the metals industry with acquisitions such as Brunswick Mining and Smelting in New Brunswick. In the mid-1970's, Noranda Mines began to buy substantial interests in major firms in the forestry industry, situated primarily in British Columbia. This was believed by corporate officers to be a logical diversification for the company into a natural resource based industry that would give good return on their surplus of capital from mining. Successive increases in the holdings of large forestry companies such as MacMillan Bloedel had given Noranda a controlling interest in a number of these firms. In the early 1980's, Noranda was the largest producer of lumber in Canada.

Tough economic conditions in the 1980's had forced the company to sell some of its interest in some holdings. Noranda had also changed the emphasis of its diversification strategy in the 1980's. Noranda bought large interests in firms that controlled or competed in markets using the metal products produced by Noranda mines. For example, it bought a controlling interest in a U.S. manufacturer of fabricated metal goods. Even during hard times the company continued to diversify aggressively.(16)

Recent Performance of Noranda

After record earnings in 1980, Noranda experienced a dramatic reversal in fortunes, as did many firms in

Canada's resource industries.(17) Table 4.3 charts the erosion of earnings, over the period 1980 to 1985, as resource markets went soft. Not only metal prices and demand slumped; lumber and paper prices and demand fluctuated under recession conditions. Of note during this period was the rapidly increasing burden of interest on the company's debt. The increase in the debt/equity ratio was partially due to Noranda's policy of continuing capital investment during cyclical downturns in markets. Unfortunately, the downturn in the markets had been longer than company executives had anticipated. Noranda in 1985 was attempting to reduce the burden of debt payments by reducing capital expenditures and selling unprofitable subsidiaries and holdings in associated companies. The losses on the sale of subsidiaries and holdings are recorded as unusual items in Table 4.3.

Recent Performance of Noranda's Mining Operations

In 1985, Noranda's mining and metallurgical operations accounted for 18% of revenues and 72% of earnings. (18) This was a significant recovery from 1981 when mining accounted for less than 12% of earnings. Earnings for Noranda's mining operations had improved since 1980-81 during a slow recovery in demand and the stabilization of metal prices.(19) Another major factor had been cost re-

TABLE 4.3 - Earnings for Noranda 1980 - 85

	1980	1981	1982	1983	1984	1985
Revenue	2,889	3,030	2,830	3,106	3,400	3,462
Expenses Excluding Interests	2,280	2,752	2,800	2,922	3,159	3,308
Interest	48	95	146	169	234	245
Earnings (Loss) Before Unusual Items	370	110	(136)	4	5	(71)
Unusual Items	47	59	57	(29)	0	(183)
Earnings (Loss) After Unusual Items	416	169	(80)	(25)	(5)	(254)

NOTE: All figures in millions of Canadian dollars.

SOURCE: Noranda Corporation

duction programs at all properties. Noranda's Chief Executive Officer (CEO) Alfred Powis, claimed in 1985 that his company had reduced the cost of producing a pound of copper by 20% between 1980 and 1985 at the same time that wages increased 20%. (20) Noranda had intermittently closed operations in various mines and mills that were unprofitable or marginally profitable rather than stockpile ore or concentrate.

There was criticism that Noranda had been too ambitious in hard times with its capital investments. These included major expansions and upgrades of milling operations and the continued exploration and development of new and existing mines. The net result of over-spending on capital projects had been the erosion of earnings by the costs of servicing the debt incurred to finance the investments. Some investments, such as the development of the Golden Giant gold mine in northern Ontario, were considered by Noranda management as an essential future stake in the mining industry. Unlike Falconbridge and INCO, Noranda was perceived by its management and people in the industry as being more reluctant to make drastic cuts in the number of employees. As of 1985, the performance of Noranda's mining operations continued to be lacklustre.

Productivity Improvement at Noranda Through Innovation

Noranda Mines in the 1980's followed the same strategy as the rest of the mining industry to cope with hard times. It had reduced its manpower by laying off personnel or by not replacing personnel lost due to attrition. Technology was used to boost the productivity of the remaining labour force. Payroll costs were thus reduced. As in the rest of the industry, technological innovation activities to improve productivity and reduce costs had proceeded on two levels. Noranda had made efforts to develop major new, more efficient mining, milling and smelting processes. Noranda was also actively involved in the encouragement of minor technological innovation by employees at its different properties. This section will concentrate on the mining and milling process innovations.

Major innovations in new process technology within Noranda fell under the mandate of the Noranda Research Center in Montreal, Quebec. Many of the technologies were experimental and years away from practical application. The Center had tended to concentrate on the metallurgy of metal processing for use in milling and smelting. The methods of extraction within mines had been given less emphasis. The Center was also concerned with environmental control.

In 1982, Noranda launched an official corporate-wide effort to get employees involved in improving both their own working conditions and the productivity of their part of the operating process at the different properties. Employee involvement was not totally new to Noranda mines and mills. Many properties already reported good relations with employees, which encouraged participation. Suggestion plans for financial reward and recognition were not uncommon. With hard times, corporate top management pushed property managers and superintendents to make employee involvement more visible and wide-spread. The resulting programs had two thrusts; first, improved productivity and reduced costs; second, improved quality of working life.

Some properties, such as Brunswick Mining and Smelting, had experimented with gainsharing schemes. (20) At Brunswick, employees were asked to submit innovative ideas for cost reduction to a three-tiered review committee process. First an idea was reviewed by supervisors and selected co-workers. Then, if found acceptable, it was reviewed by department management and union representatives. This committee approved but did not act on an idea. The administration of the program was overseen by a steering committee of management and union representatives. The company then shared 25% of the financial benefits of successful ideas with all employees in the form of a monthly bonus. The company retained the remaining 75%.

At the Geco property, 42% of the workforce had participated in over 33 task forces between 1982 and 1984.(21) Employees from the mines volunteered to work on committees for common problems and the acquisition and implementation of new technology. Each task force or employee involvement group consisted of a cross-section of employees ranging from hourly rate to management. Rewards were given to participants in the form of recognition, such as being mentioned in the company newsletter. The local union was actively involved in the program.

Efforts at other properties involved employees in seminars on cost reduction, technological change and quality of working life improvement. In conjunction with programs to improve employee relations, meetings and dinners were formally organized at many properties to encourage management/worker communication and to serve as an occasion to report to employees about the company's economic situation. Property managers and superintendents reported across Noranda's mines and mills that employees had been making significant contributions to improving operations with their ideas and cooperation.

Noranda Operations and People Involved in the Research

Groups of employees from thirteen operating units from six properties across Noranda, participated in this research. Over 100 Noranda employees contributed directly as operating unit group members or indirectly as guides, key informants and technical advisors. The term operating unit was applied to participating mine departments or mill departments. The operating units and participants were selected so as to be representative of all employees and all operating units, through-out Noranda's operations. The selection of operating units and participating employees was determined by the researcher with the help of Noranda management at both the corporate and operating unit level. The following information describes Noranda's mining operations at the time of the field research in fall of 1985.

Overview of Noranda's Mining Operations

Noranda owned or controlled 16 producing properties across Canada at the end of 1985. Participating operating units were selected from this group. In addition, Noranda operated three smelters and two refineries. Thirteen properties were in production for all or part of 1985. One of these properties, Central Canada Potash in Saskatchewan, produced muriate of potash; all the rest primarily produced metals. Noranda had interests in two other associated mining companies, namely Kerr Addison Inc. and Tara Exploration. In 1985 at the time of this research, all mining, milling and smelting operations were the responsibility of a senior vice president in Toronto. This portion of the company was further divided into four major operating groups, named Alpha, Beta, Delta and Gamma, each the responsibility of a group vice president.

Overview of Participating Operating Units

Seven mines and six mills from six properties, spread across central and eastern Canada, were selected for this research. At the time of the field work for this research, these operating units were the only mines and mills open or not in the midst of start-up of operations within Noranda. Table 4.4 lists the 13 operating units and the mineral product they extract or process. Table 4.5 lists the 13 operating units, their geographic region and which management jurisdiction (operating group) each was in. Figure 4.1 is a map of eastern Canada with the location of the participating operating units indicated. The 13 participating operating units belonged to three management groups: Beta, Delta and Gamma. No operating units were available from Alpha due to the shut-down of most of that

TABLE 4.4 - Metals Produced at Participating Operating Units

Operating Unit	Copper	Zinc	Lead	Silver	Gold	Molyb-denum
Mines						
1. Mattabi	X	X	X	X		
2. Lyons Lake	X	X	X	X		
3. Geco	X	X	X	X		
4. Horne		X		X	X	
5. Matagami	X	X		X	X	
6. Gaspe	X			X	X	X
7. Brunswick	X	X	X	X		
Mills						
1. Mattabi	X	X	X	X		
2. Geco	X	X	X	X		
3. Horne	X	X		X	X	
4. Matagami	X	X		X	X	
5. Gaspe	X			X	X	X
5. Brunswick	X	X	X	X		

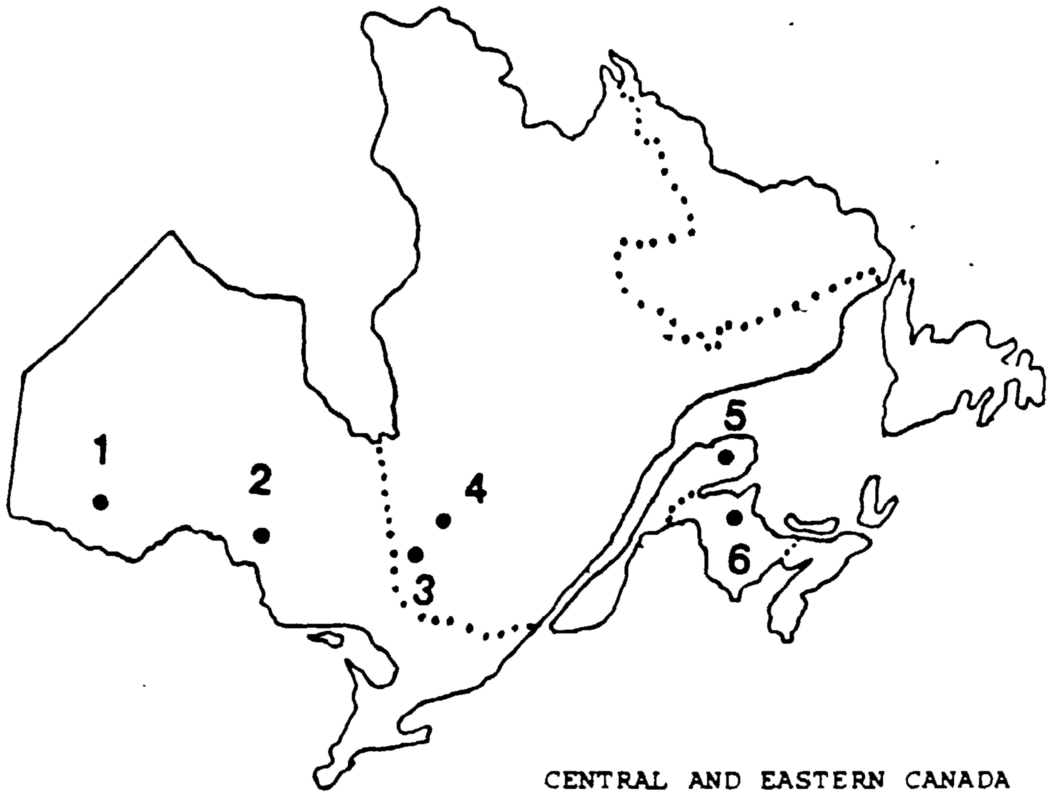
X = Extracted or Processed

SOURCE: Noranda Corporation

TABLE 4.5 - Overview of Participating Operating Units - Geographic Region and Managerial Jurisdiction

Operating Unit	Geographic Region	Management Jurisdiction
Mines		
1. Mattabi	Northern Ontario	Gamma
2. Lyons Lake	Northern Ontario	Gamma
3. Geco	Northern Ontario	Gamma
4. Horne	Northern Quebec	Beta
5. Matagami	Northern Quebec	Delta
6. Gaspe	Maritimes	Beta
7. Brunswick	Maritimes	Delta
Mills		
1. Mattabi	Northern Ontario	Gamma
2. Geco	Northern Ontario	Gamma
3. Horne	Northern Quebec	Beta
4. Matagami	Northern Quebec	Delta
5. Gaspe	Maritimes	Beta
6. Brunswick	Maritimes	Delta

FIGURE 4.1 - Location of Participating Noranda Operating Units



Participating Operating Units

1 Mattabi Mine
Mattabi Mill
Lyons Lake Mine

2 Geco Mine
Geco Mill

3 Horne Mines
Horne Mill

4 Mattagami Mine
Mattagami Mill

5 Gaspe Mine
Gaspe Mill

6 Brunswick Mine
Brunswick Mill

group's operations in 1985. Those operating units which were not in the same group were considered not to be closely related in terms of management jurisdiction. This definition was used in Hypotheses 2 and 7, in Chapter 3. The participating operating units were clustered into three geographic regions: northern Ontario, northern Quebec and the Maritimes, which included the Gaspe region of Quebec and northern New Brunswick. If operating units shared one of these regions, they were considered to be in close geographic proximity to each other; otherwise they were not. This definition of geographic proximity was used in Hypotheses 4 and 8, in Chapter 3. Note that Remnor Mine, Chadbourne Mine and Mines Gallen in Table 4.4 were combined in the operating unit called Horne Mines. This reflects the consolidation of these mines in 1985 under one mining department.

Table 4.6 lists the values for the attributes of the operating units used in the research. These attributes were used to compare operating units to determine similarity for the testing of Hypotheses 5 and 9, in Chapter 3. The mills and mines of one property can be differentiated from one another along many dimensions. After discussions with company mahagement, a number of common attributes were selected as describing mining and milling operating units. Mines and mills share a symbiotic relationship on the seven

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TABLE 4.6 - Overview of Participating Operating Units - Operating Attributes

Operating Unit	Volume (tons)	Employees	Opening Date	Mineral Reserves (years)
Mines				
1. Mattabi	370,408	94	1981	2
2. Lyons Lake	304,831	124	1980	10
3. Geco	1,438,092	287	1957	12
4. Horne	1,167,900	215	1977	3-14
5. Matagami	1,208,000	169	1963	2.5
6. Gaspe	1,111,000	207	1952	30
7. Brunswick	3,650,000	728	1960	41
Mills				
1. Mattabi	668,721	64	1971	8
2. Geco	1,438,092	91	1957	12
3. Horne	1,167,900	93	1927	...
4. Matagami	1,208,000	45	1963	2.5
5. Gaspe	1,065,000	48	1955	30
6. Brunswick	3,650,000	223	1960	41

SOURCE: All numbers are from Noranda Corporation participating properties since mine outputs usually go directly to the mill. Therefore, volume of ore and concentrate are related, as are the economic life of a mine and that of a mill. One exception to this relationship existed at Horne mill. Horne mill, in 1985, was a processor of other companies' ore as well as that which was extracted from the Horne mines. Another exception existed at Mattabi mill, where ore from Lyons Lake mine was processed as well as ore from Mattabi mine.

In Table 4.6, volume refers to the volume of ore extracted by a mine and the volume of ore processed by the mill as input. The number employed in each operating unit does not include plant personnel or office staff for administrative services such as payroll. These departments usually administer clerical duties for both mines and mills on a property. An operating unit's labour productivity was calculated by dividing the volume by the number employed. This measure of labour productivity, although crude, was commonly used in the industry. The opening date refers to when the operating unit first went into operation. Some operating units, such as Gaspe, have been opened and closed several times over their producing life. The Horne mines that in 1985 were producing the bulk of the volume, were seven years old although they are based on operations that were opened and then closed a number of times since their opening in the 1920's. The age of the operating unit was calculated from the date that the operating unit first went into production, up to October 1985. Mineral reserves are calculated by the researcher based upon 1985 rates of extraction and from Noranda's plans for each property. Mineral reserve calculations are subject to rapid change, as ongoing exploration at each mine finds new pockets of ore.

Profile of Participating Noranda Employees

Noranda employees participated in this research in a number of capacities. They served as members of the groups that suggested MTIs and which viewed MTIs from other operating units. Personal information was collected on the group members by way of a questionnaire. Approximately 50 people participated in the groups. Some people were forced by scheduling pressures to arrive late or leave early from the group meetings. Their contributions were often significant during the meetings, even if not counted as a fully attending group member. Each of the 13 operating units had been asked to supply at least three people for the group. Thirty-three or 65% of group members returned completed questionnaires. Those who didn't return questionnaires did so mainly because they did not want to or they did not have time.

A large number of employees across Noranda participated in a second capacity in this research. They helped the researcher collect the data by acting as guides and sources of confirmation or by coordinating logistics and giving technical advice. Over 100 people were estimated to have helped in this capacity across Noranda's participating operations.

Analysis of the group members' personal data produced the following profile. Thirty-six percent of group members were engineers or metallurgists, 30% line supervisors, 24% managers and department heads and 10% hourly rated labourers and tradesmen. The average age was 38 years. The average time with Noranda in its mining operations was 12 years. Forty-eight percent had worked for other mining companies. Fifteen percent had worked at other participating operating units within Noranda. During the group discussions, the researcher observed that the groups demonstrated the depth of experience with their own operations that would be suggested by the above statistics.

Generalizability of the Research Site

The study of the diffusion of MTIs between the 13 operating units within Noranda may be generalized to other firms in the same or other industries. Large firms in the Canadian mining industry, such as INCO or Falconbridge, have multiple mines and mills which could be the site for this kind of research. The economic conditions that make the innovation of minor technological innovations and their subsequent diffusion a timely issue for Noranda may also be of interest to other mining companies.

This study has concentrated on mining and milling operations within Noranda. There is no reason to infer that MTI diffusion is not an issue or opportunity of potential interest to Noranda's smelting and refining operations.

Noranda owns considerable interests in the forestry industry which is characterized by firms with multiple operating units. For instance, MacMillan Bloedel has a number of woodlots for extracting lumber, a number of sawmills and a number of paper mills for processing that lumber. Forestry is another resource industry under pressure to innovate to improve productivity and reduce costs. Noranda represents a cross-section of Canada's resource-based economy and thus represents a good starting point for research into improving operations by MTI diffusion within firms other than mining companies.

Comments and Conclusions

This chapter provides the environmental and organizational context within which the thesis research was conducted. The mining industry in Canada is portrayed as an important contributor to the Canadian economy and Noranda is one of its major firms. Noranda and its industry were confronted with a change in their competitive environment requiring major changes in how they did business. These changes included major improvements in the basic process technology of mining and in the management of people. The basic process technology is described. The organization and operations of operating units are also described. The chapter concludes its description of the research site with specific details about the participating operating units and Noranda employees in the research.

Noranda and other firms in the Canadian mining industry are aware of the importance of operating improvement to their continued survival. MTI-type innovation was recognized in the 1980's as a source of operating improvement. Noranda management was aware of the importance of employee involvement in improving operations for greater productivity and better quality of working life for employees. The need for operating improvement in Noranda and its industry provides a good opportunity to explore the contribution of MTI diffusion within firms to this end.

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CHAPTER 5

THE MINOR TECHNICAL IMPROVEMENTS

One of the more interesting facets of this research was the opportunity to witness MTIs in actual use and hear from inventors and innovators the story of how these MTIs came into use. Two questions relevant to the management of innovation and its diffusion are addressed, by examining the sample of MTIs used in this study. First, from whom and where in the organization structure of an operating unit do MTIs originate? Second, how do MTIs improve operations? If diffusion of MTIs is going to occur, knowledge of the innovations available in an originating operating unit has to be accessible to the potential user. Identifying who has this knowledge is important. If diffusion of MTIs is to occur, potential users will want to be aware of precisely how MTIs will affect their operation's performance and the magnitude of the costs and benefits.

This chapter profiles the sample of MTIs selected by the operating units and witnessed by the researcher for this thesis. The chapter includes information on who was responsible for the development of an MTI and the impact of MTIs on improving operations in the Originating Operating

Unit (OOU). Summary descriptive statistics are used to describe the 73 MTIs. More detailed descriptions of the individual MTIs are provided in Appendices 1 and 2 The Chapter ends with some summary observations about the process of innovating MTIs and the impact of MTIs on improving a unit s operations.

The Sample of MTIs

The 73 MTIs used in this research were categorized along three dimensions. This categorization is used in Chapter 6 to structure the data for hypothesis testing. First, 30 MTIs were video taped by the researcher. Half were Productivity improving MTIs (PMTIs) and the other half were Quality of working life improving MTIs(QMTIs). Twelve MTIs were from the six mills and 18 were from the seven mines. Second, 43 MTIs were documented by written descriptions edited by the researcher from interviews with Noranda employees. Thirty-six were PMTIs and seven were QMTIs. Fifteen were from mills and 28 from mines. This breakdown is summarized in Table 5.1. No significance is placed in the difference between the number of mill-produced MTIs (27) and mine-produced MTIs (46) used in this research other than that the former is drawn from six mills and the latter from seven mines. This sample of MTIs

TABLE 5.1 - Number of MTIs Documented by Category

	Video Taped MTIs		MTIs Described In Writing		
	PMTIs	QMTIS	PMTIs	QMTIs	Totals
Mills	6	6	13	2	27
Mines	9	9	23	5	46
Totals	15	15	36	7	73

was not believed to be exhaustive of all the available technology that could be classified as MTIs The sample size was limited by people s recall and ability to cooperate

Classifying MTIs as PMTIs or QMTIs was not always a straightforward process. MTIs classified as PMTIs or QMTIs often had important secondary performance effects that were characteristic of the other. Thirty-two or 44% of QMTIs and PMTIs had secondary effects on the producer s operating system. For example, new equipment and methods for handling bulk cyanide at Geco mill were implemented to eliminate serious health hazards due to cyanide fumes. Cyanide, apart from being an important reagent in the floatation process, is also a deadly poison. This MTI shortened the amount of time spent handling the cyanide, resulting in improved labour productivity for that task. At Mattabi mine, the installation of a new rock breaker layout eliminated premature machine wear and excessive downtime, resulting in improved capital productivity and output. A rock breaker is a large piece of heavy equipment, similar to a jack hammer, used to pulverize boulder-sized chunks of ore into smaller pieces for transport to the surface. The MTI also improved operator safety, air quality and eliminated fatigue due to excessive vibration. Numerous examples of MTIs in this research supported the statement that good QWL and good productivity go hand in hand.

Sources of Minor Technical Improvements

Determining the source of an MTI was complicated by the nature of the innovation process. MTIs were innovated in a variety of ways by a variety of people. What originally started out as one person's idea, ended up being modified or added to by others on its way to being successfully implemented as an MTI. Therefore the credit for innovativeness often had to be assigned to groups of individuals. At some operating units it was considered a good policy to involve as many people as possible in developing an innovation. The reasoning was that people involved in the innovation process would be more likely to accept it for use and would be stimulated to be more innovative. A number of highly visible projects of interest to people through-out an operating unit often became MTIs as the result of the initiation of a formal employee involvement committee. For example, at Brunswick mines the development of a safety vehicle for underground started out as a couple of employees' conceptualization of a means of getting firefighting and first aid teams in and out of the mine quickly with their equipment and injured. A committee of employees composed of both supervisory and hourly rated employees was subsequently struck to participate in the design of the vehicle. The resulting design looked like a well equipped jeep. Different people were credited with suggesting different features on the vehicle. Innovating by committee in this case was believed by some people at the mine to have made the project take longer to implement. At the same time, these same people believed that the process had been worthwhile in terms of producing a better design and assuring acceptance by the employees of the new technology. Thirty-five MTIs (62.5% of the 56 MTIs) were from individuals, nine MTIs (16.1%) were from informal groups and 12 MTIs (21.4%) were from formal employee involvement groups. The remaining 17 MTIs (23.3%) of the 73 MTIs sampled, were not classifiable with regards to who initiated their development.

Employees who were not management or engineering department staff, such as hourly rated employees, salaried low level technicians and their supervisors had significant input into MTI development. Table 5.2 shows the number of times an individual employee position was mentioned as being involved in the innovation process leading to the innovation of one of the MTIs used in this research. Supervisors had an important role in getting ideas implemented. Some ideas were their own and some were those of

TABLE 5.2 - Frequency of Employee Position Mentioned As Source of An MTI

Position	Cases	Percent
Supervisors	21	30.9
Hourly Rated Labour and Tradesmen	16	23.5
Metallurgists and Engineers	9	13.2
Hourly Rated and Salaried Technicians	8	11.8
Superintendents and Administrative Staff	5	7.4
Sources External to Operating Unit	9	13.2
Totals	68	100%

the hourly rated and salaried people working under them Some of the MTIs documented in this dissertation come from the same individual. At four of the operating units, a "resident inventor" was identified. This person was known within the operating unit as a consistent source of ideas with the ability to see them through to implementation. Other contributors to the successful use of MTIs were suppliers (two incidences noted), Noranda Research (2), other mining companies (1) and other operating units (8). The MTIs from other operating units were those MTIs which actually diffused between OOU and NOU in this research.

Activities to develop and use MTIs often occurred by informal means (e.g., employees developing MTIs without management authorization), as opposed to formal means such as employee involvement groups. Some informal group and individual innovation activities occurred before or without official sanction and documentation (e.g., without engineering drawings and expenditure requests). MTIs were often prototyped using scrap parts and spare time both in and outside the workplace. For example, the dry chemical fire extinquisher filler developed at Mattabi mine was first prototyped by a carpenter in his home basement. It was subsequently brought into the operating unit, where it got regular use.

In the case of 27% of the MTIs, suppliers to an operating unit played a supporting role in developing an MTI. This often meant providing information about products and manufacturing techniques, building prototypes and/or mass producing subsequent replications of an MTI. For example, the resident "inventor" at Brunswick mines had developed a relationship with a number of local businesses and national mining suppliers to prototype innovations. These businesses were sometimes given the rights to manufacture the MTI for Brunswick and market the technology to other companies. This was done in the case of the cablebolt feeding machine documented in Chapter 7

The Problems and Opportunities For Minor Technical Improvement

At least 95% of the MTIs were need "pulled" rather than technology "pushed". Most responded to persistent and irritating problems. Some problems and inefficient practices had been standard procedure for some time before a better way was found. For example, the cleaning of large equipment parts by brush and solvent had been a time-consuming and much disliked task at Lyons Lake mine for years. The problem was solved by the in-house development of a cleaning tank which would scour the parts overnight.

All the MTIs sampled in this research involved the replacement of an older method or piece of hardware or method. MTIs were innovated usually in one of three major ways, as summarized in Table 5.3. The allocation of an MTI to one of the three strategies was determined by the researcher after observing where the MTI fit into the operating system and the MTI's history. Participants in the research had a fondness for displaying stand-alone "gadgets" such as the Cappel Remover used at Mattabi mine. This was a new piece of technology developed in-house to remove a safety hazard associated with regular maintenance on the hoist cable. It consisted of a number of pieces of sheet metal and angle iron specially fitted and shaped for the Mattabi shaft. It was designed and made on-site.

Some of the MTIs developed in-house involved applying basic principles of science in innovative ways. For example, the continuous polymer feeding system at Geco mill made use of scientific knowledge of the flow properties of fluids, to design a better mixing process. This approach was a low cost alternative to a more expensive and less effective mechanical agitation method.

TABLE 5.3 - Three Major Ways MTIs are Innovated

Strategy	Number Of MTIs	Percent
Development in-house of new equipment and/or methods.	40	54.8
Modification of existing equipment and/or methods.	17	23.3
Purchase of appropriate new equipment and/or methods.	14	19.2
Unclassified	2	2.7
Totals	73	100%

Some operating units improved operations by modifying existing equipment and methods. For example, at Matagami mines, most of the BBC-120 drills were modified, which reduced significantly equipment maintenance costs. The drills were used to make holes for blasting charges in the stope walls. The modification involved replacing some of the drill's original fittings with home-made fittings.

The purchase of new technology from suppliers was often key to the innovation of an MTI. For example, at Brunswick mill, radio headsets were purchased to direct overhead crane operation in areas of poor visibility. Prior to the headsets, workers had to rely on hand signals or awkward cord phones to direct the crane operator, who was often out of direct eye contact. The mill bought the headsets from a supplier.

Some MTIs in the sample were related to each other in that they were components of a new sub-system. The cable-cutting device and cablebolt feeding machine were both part of a new approach at Brunswick mine to cablebolting underground. The cablebolt feeding machine fed the cable up into the drilled holes in the tunnel ceiling to secure the rock. The cable-cutting device sheared off the cablebolts as the ceiling was incrementally blasted away to release ore-bearing rock. The cable cutting device could also be used to cut reinforcing rods and other structural materials. Some MTIs, such as the copper sulfate mixing and feeding system at Mattabi mill, could be considered as two innovations in one. In that case, the delivery of the reagent copper sulfate in bulk bags to a hopper device could be considered one innovation. The second could be the use of an automatic feeding system developed by Noranda Research to inject the copper sulfate into the floatation process.

The Impact of MTIs on Improving Operations

A number of dimensions of operating performance were affected by MTIs. Productivity improved both by the better use of productive inputs and increased output. Quality of working life improved through better job design and health and safety. Although not as tangible, the latter improvements were considered important by management and employees at various levels in the research site. The following section relates some of the costs and benefits of MTIs within the operating units that innovated them.

Productivity Improvements

The MTIs used in this study affected the productive use of a variety of inputs and outputs. Improvements in the use of the inputs of labour, materials and capital and/or output were quantified. Labour-saving MTIs often reduced the man-hours per task or the number of people assigned to a job. This did not necessarily mean that a person was dismissed or laid-off. Material savings involved reducing the cost of commodities consumed by the operating system to extract and process the minerals (e.g., reagents and explosives). Capital savings were realized through decreased consumption of fixed assets, such as buildings and production equipment. Output was increased either through improved quality (e.g., higher yields of concentrate), decreased downtime due to interruptions (e.g., scheduled maintenance) or breakdown. The result was increased demonstrated capacity. Table 5.4 records the number of MTIs in either mills or mines that were attributed with affecting a particular input/output component. Note that more than one component can be effected by an MTI. QMTIs as well as PMTIs had net positive effects on productivity as an indirect consequence of their implementation.

Mines and mills appear to differ in their experiences with the effects of MTIs on productivity. Factors affect-

TABLE 5.4 - The Frequency That Productivity Factors Were Affected by MTIs

	Mills (n=27)		Mines (n=46)	
	Number of MTI	Percent of All Mill MTIs	Number of MTI	Percent of All Mine MTIs
Inputs				
Labour	12	44.4	31	67.4
Materials	6	22.2	10	21.7
Capital	3	11.1	8	17.4
Outputs				
Quality	5	18.5	4	8.7
Downtime	6	22.2	5	11.0
Volume	7	25.9	8	17.4

ing improving and maintaining output were mentioned more frequently for mill MTIs than mine MTIs (66.6% and 40% respectively). The higher mill percent when compared to that for mines, reflects the critical operating requirement in a mill for a smooth continuous flow of materials and good recovery of metals from the ore. There were fewer opportunities to decouple the milling production process. Both mine and mill MTIs had a significant impact on labour productivity (67.4% and 44.4% respectively). These improvements involved the addition, substitution or replacement of a particular piece of equipment. The focus on labour productivity is partially explained, by the fact that labour costs accounted for between 35% and 55% of the total operating costs for a mine. The higher percentage of labour productivity improving MTIs from mines when compared to mill MTIs, reflects the greater labour intensity and lower level of automation associated with mines. Compared to MTIs from mines, 17.4% as opposed to 11.1% of MTIs from mills, were considered capital saving. Mines tend to damage or lose expensive capital equipment at a rapid rate, Most mine superintendents at Noranda were sensitive to reducing these costs. The cost of labour and material inputs required to maintain capital equipment and assets can consume as much as a third of a mine's operating budget.

Quality of Working Life Improvements

Table 5.5 shows the number of mine and mill MTIs that were attributed with improving aspects of the quality of working life. Two aspects of QWL emerged as being of major importance to operating units, namely working conditions and safety. "Working conditions" refers to improved air quality, workplace cleanliness, and ergonomics of machinery operation. Improvements in safety corrected situations that were potentially injurious to employees. In mills, the handling of poisonous or caustic chemicals was reduced. In mines, the handling of explosives was reduced, back and crush injuries diminished, and fire hazards were remedied. More mine MTIs were attributed with affecting QWL, especially in the area of safety, than were mill MTIs. Of mining MTIs, 41.3% were safety improving as opposed to 25.9 % for mill MTIs. The difference is difficult to explain conclusively, but the risks of injury in a mine were usually perceived to be higher than in a mill by both mill and mine personnel. Thus, there may have been a greater sensitivity to safety-improving MTIs on the part of miners.

Job design aspects of QWL were affected by some MTIs. In two cases, the use of microchip technology affected productivity by improving job design. The installation of a microcomputer at Horne mine was presented by operating unit personnel as an example of a QMTI. It allowed engineers in the office to minimize clerical duties and concentrate on

TABLE 5.5 - The Frequency That QWL Factors Were Affected by MTIs

	Mills (n=27)		Mines (n=46)	
	Number of MTIs	Percent of All Mill MTIs	Number of MTIs	Percent of All Mill MTIs
QWL Component				
Safety	7	25.9	19	41.3
Working Conditions	8	29.6	12	26.1

the engineering they were trained to do. When remote graphic analysis terminals for the zinc circuit were placed on the mill floor at Horne mill two improvements in the operator's job resulted. First, the information was presented in a form more amenable to trend analysis. Second, the operator could now get out of the control booth and seek out problems on the mill floor without losing touch with the monitoring of the overall process.

Economic Costs and Benefits

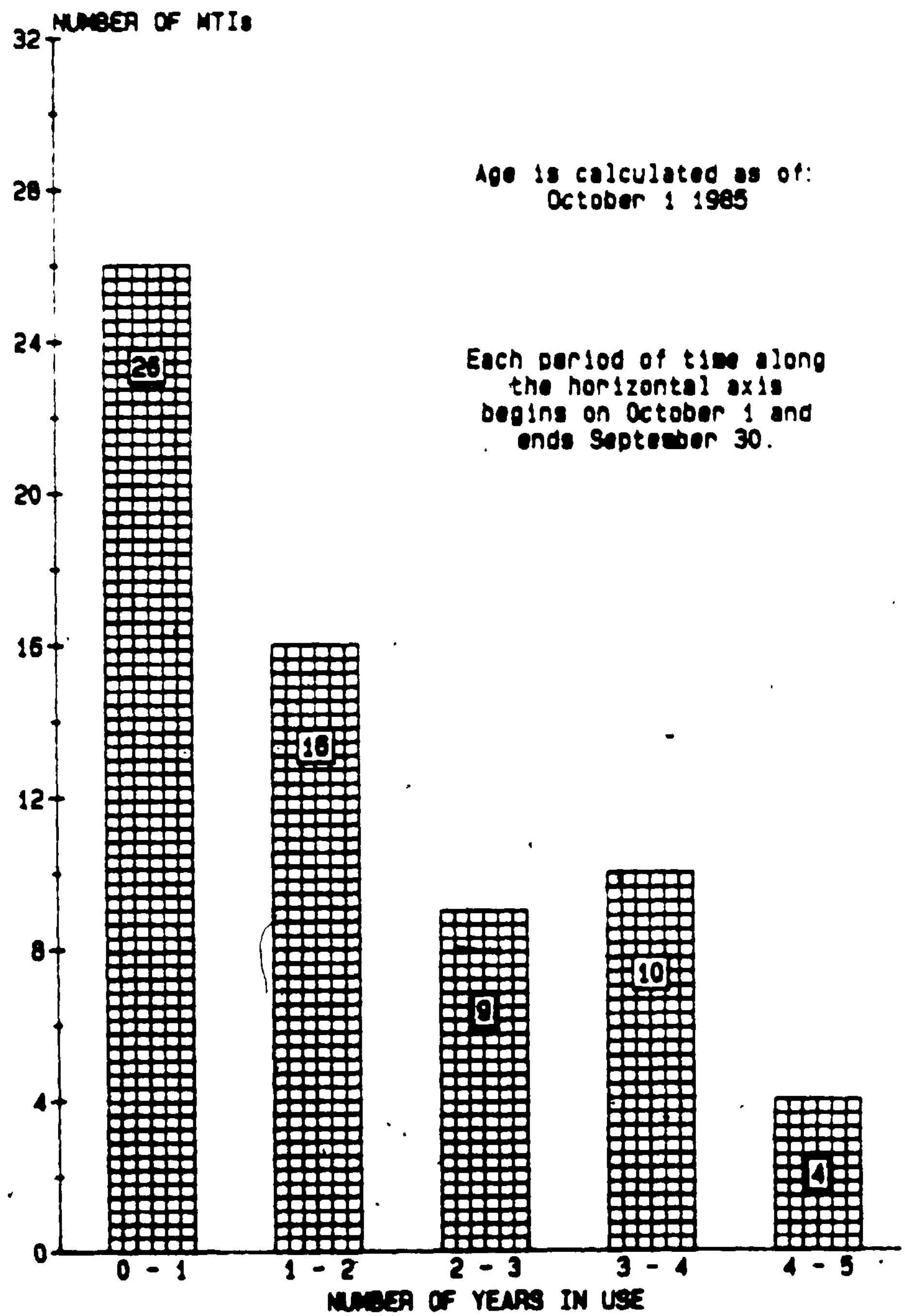
The average MTI examined in the research was inexpensive to develop and implement and resulted in relatively large revenues and/or savings. An MTI cost on average $5,025.40, representing the relevant costs of labour and materials required to implement the first use of an MTI successfully. The distribution of costs for the 73 MTIs was heavily skewed. Most were even cheaper, with a median of $1,347. Costs ranged from practically no out of pocket costs to $37,000.

MTIs saved on average $41,459 annually. The median of $9,500 suggests that the distribution of individual MTI savings is skewed lower. Some MTIs realized part or all of their savings in the first year of their successful implementation. Others continued to accrue benefits after the first year. When this fact is taken into account, the total savings over the life of an MTI, as of October 1985, rose to an average of $57,455 and a median of $14,826. The maximum annual saving for an MTI was $500,000. The maximum saving over the life of an MTI was $1.5 million. The minimum saving by both means of accounting was 0. This minimum was not uncommon since many QMTIs were not implemented for economic reasons. The averages for the returns and savings reflect the influence of a few very beneficial MTIs. For example, the regular use of a new friction washer at Brunswick mines had savings of $500,000 a year associated with its use over three years, for a lifetime savings of $1.5 million a year. Brunswick used thousands of friction washers every year as part of its rockbolting operations to secure the tunnel walls.

The total net savings over the life of the MTIs described in this research are estimated at $4.2 million. The methodology used for calculating total net savings over the life of those MTIs sampled, is shown in Appendix 5. The average productive life of an MTI in this study, as of October 1985, was less than two years. Figure 5.1 contains a graph of the distribution of ages of the MTIs indicating the length of time the MTIs had been benefiting operations.

71

FIGURE 5.1 - Distribution of Ages of MTIs



These MTIs were attractive investments for the various operating units. An MTI on average had a payback period of 2.9 months. The distribution of payback periods was skewed, as suggested by a median payback of less than one month. The maximum payback period was two years. The minimum payback was almost 0 or immediate, as in the case of MTIs which deferred expensive capital acquisitions. For example, the polymer feeding system from Geco avoided the purchase of a more expensive piece of equipment. In summary, the initial capital outlay to develop an MTI was low, the returns attractive and the time needed to realize them was short.

All of the above figures are approximations based upon the recollection and documentation supplied by operating unit personnel. Cost and benefit data were not complete for all 73 MTIs. However, the available data were, from the researcher's observations, representative of the economics of all 73 MTIs. The documentation needed to assess costs and benefits was often not available because of the sometimes informal nature of the innovation process. However, costs to develop a working prototype of an MTI or test a new method could in some cases be obtained from purchase orders, memos and material requisitions. Unfortunately, after the MTI appeared to be working successfully in the opinion of operating personnel, further monitoring of the costs and benefits was not continued. A common way to account for an MTI's benefits was in terms of labour dollars saved. Man-hours or years saved at one task in most cases did not result in a reduction in operating unit personnel since most people were reassigned to other tasks. Downsizing by layoff and headcount reductions at all operating units had resulted in fewer people doing more in less time. Therefore some of the labour savings were needed to fill a deficit in the required manpower.

Comments and Conclusions

From the experience acquired in the course of this thesis in documenting MTIs, it would seem that the best way to "ferret out" MTI-type innovations in an organization is to talk to as many people in line positions as possible as often as possible. Caution is recommended in dealing exclusively with traditional technological gatekeepers, such as the operating unit superintendent, who may favour only certain "pet" projects. The largest problem in documenting the MTIs used in the research was the lack of accurate recall by individuals and groups about events more than a year old. As indicated in the skewed distribution of ages in Figure 5.1, there may have been a bias towards recounting only the more recent MTIs. The skewing of the age of the MTIs may also be attributed to the gradual change over the last five years in employee and management attitudes at Noranda towards a recognition of the need for more minor technical improvements. Getting a number of people's perceptions about a given MTI was considered important in getting the facts straight. Precise dates, amounts and the innovation process details often had to be pieced together from a number of sources.

In summary, a number of interesting observations were made about MTI-type innovations in terms of where they came from and how they improved operations within the Noranda operating units. Productivity and QWL improvement were mutually supporting in many MTIs. Labourers, technicians and their supervisors were important sources of MTIs. The majority of MTIs involved the in-house development of new equipment and methods. Mills and mines differed in their focus for productivity improvement. Productivity-improving MTIs affected labour inputs more frequently than any other output or input. Precise cost/benefits analysis was not perceived to be a necessary requirement for the development of an MTI. MTIs may be sensitive to being forgotten in the collective memory of the operating unit after a year or two. The initial capital outlay to develop an MTI was low, the returns attractive and the time needed to get payback brief. Significant cost savings were estimated to have accumulated within individual operating units in this research as a result of MTI innovation

CHAPTER 6

HYPOTHESES TESTING AND OTHER QUANTITATIVE ANALYSIS

Three major findings come out of the testing of the hypotheses for this research. First, some MTIs have indeed diffused from OOU to NOU. Second, even more MTIs were considered by NOUs to be potentially useful and thus potentially diffusable. Finally, under the circumstances of this study, actual and potential diffusion were not found to be influenced by some variables suggested by the literature and common sense.

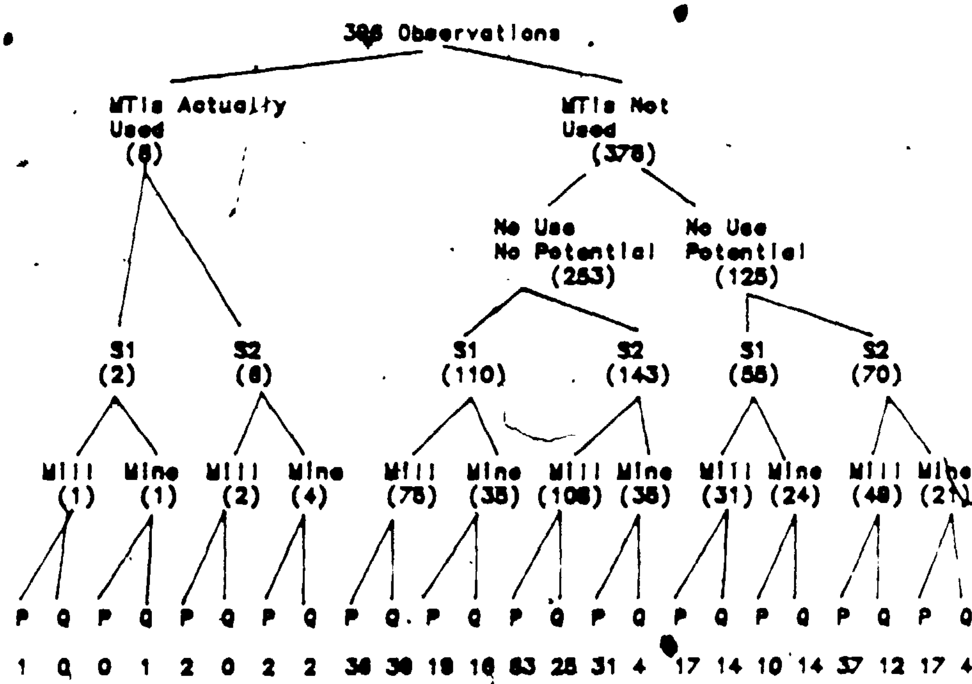
This chapter focuses on the results of the statistical testing of the hypotheses using data from the field study. The results of the hypothesis testing are then interpreted. Chapter 7 focuses on the qualitative aspects of these findings, as well as other findings not hypothesized prior to the research.

Results of the Data Collection

A total of 396 observations were analyzed to test the hypotheses. Each observation represented one non-originating unit s (NOU) response to a MTI from an originating operating unit (OOU). Eight observations were made of an MTI from an OOU actually being used by an NOU. The remaining 378 observations were responses by NOUs that they were not using an MTI. Of these observations, 125 observations indicated the potential use of an MTI by an NOU. Ten of the observations were unclassifiable. Figure 6.1 contains a breakdown of the collected observations.

Three facts became evident during the course of the data collection. First, early in the field study it was found that the milling operating units were not interested in MTIs from the mining operating units and vice versa. Although mills and mines are closely linked in the mining process, employees involved in either a mine or mill saw very little overlap with the other type of operating unit in terms of the operating conditions and the process technology requiring innovation. Second, the use of video tape to document MTIs and elicit responses about MTIs was observed by the researcher to generate much more enthusiasm than the written descriptions of MTIs. Video tape equipment was familiar to all the operating units visited by the researcher. Similar equipment had been used to develop education materials for technical skill and safety training. Finally, it was often difficult for the groups at each operating unit, both in selecting and responding to MTIs, to

FIGURE 6.1 - Breakdown of Observations For Data Analysis

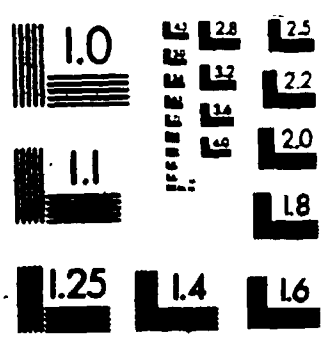


Q = QMTI
P = PMTI

() = Cell Count

3

MICROCOPY RESOLUTION TEST CHART
NBS 1010a
ANSI and ISO TEST CHART No. 2



differentiate whether an MTI was primarily productivity-improving or QWL-improving. Some NOU groups saw different advantages in an MTI than the OOU. The observation in Chapter 5 that productivity and quality of work life improvement are closely linked in the innovation of MTIs may be a possible explanation.

To accommodate these three observations, the statistical analysis first outlined in Chapter 3 was extended. To highlight possible differences between mines and mills in the actual and potential diffusion of MTIs, observations between mines were examined separately from observations between mills whenever the number of available observations permitted. To detect possible instrumentality and selection biases, observations involving the video taping of MTIs were examined separately from observations involving written descriptions of MTIs. Finally, observations involving PMTIs were examined separately from observations involving QMTIs. These refinements basically involved isolating a subsample of all observations and applying the tests of the hypotheses to them.

Figure 6.1 also summarizes how the collected observations partitioned into subsamples. Unfortunately, not all contingencies could be explored because of small cell sizes which invalidated the statistical tests.

Summary of Hypothesis Testing Results

This section summarizes the results of the statistical testing of the hypotheses, with the significant statistic reported individually for each hypothesis. A probability of less than or equal to 5% on a one-tailed test was grounds for rejecting the null hypothesis and supporting the research hypothesis (Alternative). The results are presented so that support or no support refers to the alternative or research hypothesis. The significance level refers to the probability of falsely rejecting the null hypothesis.

	NOT/ SUPPORTED (Significance Level)
ACTUAL ADOPTION HYPOTHESES	
HYPOTHESIS 1: A greater number of MTIs will be in use in more than one operating unit.	NOT SUPPORTED ($P < .0001$)
HYPOTHESIS 2: The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by the NOU.	NOT SUPPORTED ($P = .1094$)
HYPOTHESIS 3: The greater the geographic proximity between an OOU and an NOU, the greater the likelihood that an MTI will be actually be used by the NOU.	NOT SUPPORTED ($P = .2188$)
HYPOTHESIS 4: The more similar the processes between an OOU and an NOU, the greater the likelihood	NOT SUPPORTED

that an MTI will be actually used by the NOU. As measured by:

Output Volume	(P =.2188)
Manpower	(P =.2734)
Labour Productivity	(P =.1094)
Mineral Reserves	(P =.3125)
Age of Operating Unit	(P =.2188)

HYPOTHESIS 5: An MTI will be adopted by an NOU during a limited time period after being innovated by the OOU or it will not be adopted at all.	NOT SUPPORTED (P =.2188)
HYPOTHESIS 6: PMTIs will be actually used by a greater number of NOUs than will QMTIs.	NOT SUPPORTED (P =.3088)

POTENTIAL ADOPTION HYPOTHESES

HYPOTHESIS 7: The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU.	NOT SUPPORTED (P = 1.0)
HYPOTHESIS 8: The greater the geographic proximity between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU.	NOT SUPPORTED (P =.2749)
HYPOTHESIS 9: The more similar the processes between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU. As measured by:	NOT SUPPORTED

Output Volume	(P =.658)
Manpower	(P =.382)
Labour Productivity	(P =.719)
Mineral Reserves	(P =.910)
Age of Operating Unit	(P =.535)

HYPOTHESIS 10:
PMTIs will be perceived as potentially useful to a greater number of NOUs than will QMTIs — NOT SUPPORTED (P = [illegible]8[illegible])

Discussion of Hypotheses Results for The Actual Diffusion of MTIs

The low number of observations of actual diffusion of MTIs between operating units necessitated using all observations of actual diffusion without further breakdown by medium, operating unit type and MTI type. This section provides interpretation and supplementary analysis for each hypothesis. Additional information about how the data was organized for testing and the tests applied, is provided in Appendix 4.

HYPOTHESIS 1:
A greater number of MTIs will be in use in more than one operating unit. — NOT SUPPORTED (P < .0001)

There was insufficient evidence that MTIs diffused further than the operating unit they originated within. There was a statistically significant difference between the number of MTIs that did diffuse compared to those that did not. But the difference was the opposite of what was hypothesized above. A lesser number of MTIs were in use in more than one operating unit

Seven of the 73 MTIs (9.6%) sampled were found to be actually in use by operating units other than the OOU. Eight observations were made of an NOU responding that it was using an OOU s MTI. Seven different MTIs were being used by seven different NOUs. One MTI was being used in two NOUs. Four of the MTIs were from mining operating units; two were PMTIs and two were QMTIs. Three of the MTIs were from mill operating units and all were PMTIs. Six of the observations involved video taped MTIs and two were written descriptions of MTIs. No mine MTIs were used by a mill, and vice versa.

HYPOTHESIS 2:

The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be actually used by the NOU.	NOT SUPPORTED (P =.1094)

Of the eight observations of actual diffusion, two were within the same management group and six were between groups. This is the opposite of what would be expected. Actual use would have been expected to occur more often between operating units that shared a regional division. A possible explanation may lie in the decentralized organiza-

The heightened awareness of health and safety issues in the mining industry may explain the lack of support for this hypothesis. Groups from the operating units were composed of a cross-section of hourly rated, salaried and management personnel. The operating units involved in this research had a history of meeting in groups similar to those used in the research, for the express purpose of considering improvements to the quality of working life. Therefore the groups were receptive not only to PMTIs which addressed management's interest in cost performance but also to QMTIs that directly affected the work environment.

Results of Statistical Testing of Other Possible Influences on Diffusion

During the course of the field studies, data were collected on the age, initial costs, and annual net savings associated with some of the 73 MTIs. This information is presented in both Chapter 5 and Appendix 5 in more detail. Binomial tests were used on the MTIs that actually diffused, and median tests on the MTIs that could potentially diffuse, to test if age, costs and net savings might influence how NOUs responded to an MTI.

Mineral Reserves	(P =.3125)
Age of Operating Unit	(P =.2188)

There is no evidence from this low-powered test of limited data that the degree of similarity between OOU and NOU as measured by output volume, manpower, labour productivity, mineral reserves and the age of the operating unit unit was related to whether an NOU would actually use an MTI. The only supportable aspect of this hypothesis was that no mine actually adopted a mill MTI, and vice versa. During the course of the presentation of the video taped MTIs to the NOUs, group members were reluctant even to view MTIs from the other type of operating unit, even if it was from the same property.

HYPOTHESIS 5:

An MTI will be adopted by an NOU during a limited time period after being innovated by the OOU or it will not be adopted at all.	NOT SUPPORTED (P =.2188)

There was no evidence that the younger MTIs were more likely to be used by an NOU than the older ones or vice versa. Due to the small number of observations, there was no means of conclusively establishing whether there was a critical period that was neither too early nor too late. Later in the chapter, there is some evidence that, although people in OOUs may be interested in talking only about their most recent MTIs. NOUs often found many older MTIs potentially useful.

HYPOTHESIS 6:

PMTIs will be actually used by a greater number of NOUs than will QMTIs.	NOT SUPPORTED (P =.3088)

As suggested in Chapter 5, the distinction between PMTIs and QMTIs was not often clear cut. Some PMTIs had QWL benefits and some QMTIs had productivity benefits. Five of the MTIs actually used by an NOU were classified as PMTIs and two as QMTIs. Both Chapter 5 and Chapter 7 contain evidence of the close relationship between productivity and quality of work life.

Discussion of the Hypotheses Results for the Potential Diffusion of MTIs

There were 378 observations of NOUs not using a given MTI. Of this number, 125 observations (33%) recorded that an NOU considered a given MTI potentially useful. Observations of an MTI not being used but being considered potentially useful were tested for differences against those observations of an MTI not being used and considered not potentially useful.

The proportion of observations where NOUs responded that an MTI was potentially useful (relative to not potentially useful) did not vary when mines were compared to mills, video taped MTIs to written descriptions and PMTIs to QMTIs, except in one possible instance. Of those MTIs video taped, a significantly greater proportion of QMTIs from mills were considered by other mills to be potentially useful as compared to QMTIs from mines being considered by other mines (CHI SQ. = 3.51457, SIG. = 1024). This finding was not supported by a similar test of all MTIs in Hypothesis 10. The possible explanation for this result may be that the mines were more critical in how they evaluated QMTIs, especially those related to safety practices. Some of the QMTIs presented on video tape did not "look" right to the NOU groups; thus, they did not wish to use them.

Chi squared tests were performed to determine if there were significant differences between observations of MTIs not used and MTIs not used but of potential use. A significance level of .05 was used throughout the hypotheses testing. The results are discussed for each hypothesis

HYPOTHESIS 7:

The more similar the management jurisdiction between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU.	NOT SUPPORTED (P = 1.0)

The lack of support for this research hypothesis reinforces an observation made earlier that the decentralized management practices of the research site may have made management jurisdiction a minor influence on diffusion. The three operating groups involved in this research were organized on the basis of geography and some consideration of the minerals produced. The effect of being under different senior management does not seem to influence the receptiveness of operating groups to MTIs from operating units in other operating groups.

HYPOTHESIS 8:

The greater the geographic proximity between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU	NOT SUPPORTED (P = .2750)

The effect of the medium used to communicate MTIs to NOUs was examined for its effect on the testing of this hypothesis. A significant but conflicting result was found. PMTIs described in writing and from mines tested significant. Those OOUs and NOUs that were closer to each other in terms of distance, were more likely to perceive an MTI as potentially useful. No significant result was found for PMTIs video taped and from mines. The discrepancy between the results of testing the hypothesis against all observations and against only those that involved written descriptions of MTIs, could be the result of a number of factors.

There may have been a methodological bias that influenced the above results. The video taped MTIs may have been perceived by the NOU employees as more accessible The distance they might have to travel or communicate to acquire the MTI was not foremost on their minds Seeing the MTIs on video tape may have provided sufficient information to make a decision about using an MTI, without travel or further communication. The MTIs described in writing were possibly less accessible, causing the NOU employee to consider the effort needed to get more information through travel or some other form of communication.

The mixed results from the subdivided data may also be due to a selection bias. The observations with written descriptions had a greater number of MTIs which were from mines and that were productivity-improving. These MTIs were strongly linked to the actual mining methods used, which were in turn related to the geology and history of a region. The recognition of this common background, coupled with the sparser information conveyed by the MTIs described in writing, may have encouraged respondents to give an MTI from a neighboring operating unit the benefit of the doubt and respond that an MTI was potentially useful.

HYPOTHESIS 9

The more similar the processes between an OOU and an NOU the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU As measured by:	NOT SUPPORTED
Output Volume	(P =.658)
Manpower	(P =.382)
Labour Productivity	(P =.719)
Mineral Reserves	(P =.910)
Age of Operating Unit	(P =.535)

The hypothesis is supported in that there is a strict division between mine and mill technologies. A mine did not consider seriously a mill MTI as potentially useful, and vice versa. The hypothesis is not supported in that similarity between NOU and OOU, using five measures of common attributes used to describe mines and mills, affects whether an MTI has the potential to be regarded as usable.

All five measures tested against all observations produced no significant results, but disaggregation of the observations into video taped MTIs and written descriptions of MTIs produced an interesting result. For observations involving written descriptions of MTIs, output volume was significant at the .0328 level. The direction indicated by examining the cell frequencies supports the hypothesis. The more similar the processes between an OOU and an NOU, the greater the likelihood that an MTI will be perceived to be potentially useful by the NOU. There is an obvious conflict between the results for all observations and those for just written descriptions.

Both selection bias and methodological bias may account for the different results. A selection bias may have existed in deciding which MTIs to video tape. Participants may have tried to anticipate what other operating units might consider interesting. This situation may have been further accentuated by the request that OOUs pick their best productivity and QWL MTI. They had no guarantee that they would be able to present all their other MTIs in written form.

A methodological bias may have existed because the video taped MTIs were presented with less uncertainty due to the nature of the medium. This accessibility to information could have given operating units quick and accurate information to overcome uncertainty and progress to making a decision. Feedback from the participants during the presentation of the video taped MTIs frequently mentioned the usefulness of seeing a piece of technology in action, in order to make a firm decision whether to use it.

HYPOTHESIS 10:

PMTIs will be perceived as potentially useful to a greater number of NOUs than will QMTIs.	NOT SUPPORTED (P =.787)

The heightened awareness of health and safety issues in the mining industry may explain the lack of support for this hypothesis. Groups from the operating units were composed of a cross-section of hourly rated, salaried and management personnel. The operating units involved in this research had a history of meeting in groups similar to those used in the research, for the express purpose of considering improvements to the quality of working life. Therefore the groups were receptive not only to PMTIs which addressed management's interest in cost performance but also to QMTIs that directly affected the work environment.

Results of Statistical Testing of Other Possible Influences on Diffusion

During the course of the field studies, data were collected on the age, initial costs, and annual net savings associated with some of the 73 MTIs. This information is presented in both Chapter 5 and Appendix 5 in more detail. Binomial tests were used on the MTIs that actually diffused, and median tests on the MTIs that could potentially diffuse, to test if age, costs and net savings might influence how NOUs responded to an MTI.

A median test on Age produced a significant association between whether an MTI had the potential to be adopted and the date of origin (Chi Square Median Test = 4.1296 Significance = .0421). Examination of the cell counts for the more recent observations versus older observations suggests that even though operating units tend to offer their more recent MTIs for consideration, NOUs were also interested in the older MTIs. Figure 5.1 in Chapter 5 presented the distribution of MTIs' ages. The ages of the MTIs offered by OOUs are skewed in their distribution to their more recent efforts. Of those responses indicating no potential use of an MTI, 43% were greater than the median age of 1.5 years. Of those responses indicating potential use, 54.3% were more than the median age. The implication is that the search for potentially useful MTIs in an operating unit should extend beyond that which is suggested by employees from recent memory, to encouraging a careful review of past efforts.

The magnitude of the costs and savings associated with individual MTIs was not found to influence whether an MTI will be considered potentially useful in this research. For QMTIs, whose primary benefits were not economic, this was not a surprising finding. There was no statistically discernible relationship between how many operating units considered the potential use of an MTI and the costs and benefits associated with that MTI. The research suggests that when an NOU is first exposed to an MTI, the evaluation of an MTI's potential may hinge on whether it is functionally useful; then the economics are considered in more detail. It should be noted that the operating units were not expressly instructed to do detailed cost benefit analysis on each MTI they viewed.

Comments and Conclusions

Of the 73 MTIs studied in this research, seven MTIs (9.6%), diffused from one operating unit to another. In each case, someone in the NOU thought a piece of minor technology was of sufficient value that the process of adopting the MTI was initiated. Although all of the seven MTIs had some direct or indirect economic benefit, two were primarily QWL improving. Economics was not the only benefit sought in using an MTI.

The observations of actual diffusion were recorded after the fact. Diffusion occurred without the intervention of the research methods used in this thesis, in an environment within the research site which did not offically encourage such activity. The trickle of MTI diffusion occurred in spite of geographic distance, the need to cross organizational boundaries and the aging of information about the MTIs. There was no evidence to suggest that actual diffusion occurred only between operating units that were similar to each other. Despite the barriers to diffusion, referred to in the diffusion literature as tending to localize technology in its place of origin, some MTIs did diffuse. Given these conditions, the interesting follow-up question asked in the next chapter; should be: how did they diffuse then?

One effect of the field work in this thesis was to communicate the existence of potentially useful MTIs to NOUs that had not been exposed to MTIs from other operating units. Eighty-two percent of the MTIs were found to be potentially useful by NOUs. A comparison of the smaller number of observations of MTIs that actually diffused to the large number of observations of MTIs that could potentially diffuse, strongly suggests the need for greater communication among operating units. Without the awareness created by the research, there was a low likelihood that many NOUs would have heard of an MTI and thus been able even to consider its potential use.

Before any technical and economic merits of an innovation can be considered, there must be awareness of what is available. Only when confronted with 73 MTIs, proven successful in another operating unit, did NOUs have an opportunity to make some tentative decisions about adoption. An interesting finding was that even older MTIs, which had been around for a while, were considered to be potentially useful by some operating units. The implications of this finding are that NOUs do not "get around" to other operating units nor are they often re-invented elsewhere if not diffused. During all the field work the researcher found very few incidents of truly identical but independently developed MTIs. Unless an MTI's diffusion is actively pursued, the MTI and its associated benefits go unduplicated elsewhere in the firm.

According to Rogers, the more similar individuals, groups and organizations, the more likely they are to communicate.(1) The more two operating units communicated, the more likely an MTI would be expected to diffuse if useful. Similarity was measured, in this thesis, in a number of ways using commonly recognized means for describing operations in the mining industry. Similarity was not supported as an influence on either actual or potential diffusion. Common management and geographic region also did not influence either actual and potential diffusion. Given the research site's concern with economic survival, it had been anticipated that PMTIs would be communicated and diffused or at least be considered potentially useful more often than QMTIs. This was not the case in circumstances of the research.

Similarity between innovator and potential user may still be important to diffusing innovation. The relevant focus should perhaps not be on the importance of similarity between operating units in general ways such as output volume and manpower. Rather, awareness between operating units of the degree or lack of compatibility of specific equipment and methods may be the more powerful influence on whether people from one operating unit will communicate information about MTIs to other units that could potentially lead to diffusion. As mentioned in Chapter 5, many MTIs involved modifications or inventions that interfaced with specific operating equipment and processes. There was considerable variation in the make and model of equipment and processes, but not the function that they performed, among operating units. It is at this level of detail that similarities between operating units are possibly important.

How information is communicated about MTIs may be important in determining the extent of diffusion. Different results were encountered in the testing of the hypotheses, depending on whether the MTIs were presented on video tape or in writing. The video tape medium produced the richest source of information about an MTI. MTIs presented visually may have allowed potential users to make more objective evaluations of the MTI. The MTI could be viewed in action, in its normal operating context. Moreover, the use of video tape may have its own associated selection biases. An MTI that is not as visual, such as an improvement in a clerical proceedure, may not be as interesting to watch as a highly visible task involving people and machinery in action.

In summary, some MTIs did diffuse between operating units and there exists a significant potential for further diffusion. Communication leading to awareness of potential MTIs among the appropriate people in NOUs may be the route to greater actual diffusion of MTIs. The general proposition is not supported that the greater the similarity between operating units, the more likely actual diffusion or the greater the potential for diffusion. The use of general attributes of the operating units and the sampled MTIs was not useful in explaining actual and potential diffusion. Similarity between OOU and NOU may be important but possibly on the basis of more specific details about the process. The communication between operating units of details such as equipment compatibility may be a more useful way to facilitate diffusion. There are some indications that given a greater number of observations of actual use and tighter controls for the medium used to present the MTIs to respondents, some attributes such as geographic proximity might have been found to be a significant influence on MTI diffusion. As will be indicated in the next chapter, the means to improving operations by intra-firm diffusion of MTIs may lie not so much in communication between those operating units that are most similar in obvious and general ways, but in the persistence of operating unit personnel from all operating units in sending and receiving information about MTIs from all operating units.

References

(1) E.M. Rogers, Diffusion of Innovation 3rd Ed. (New York: The Free Press, 1983), p. 18.

CHAPTER 7

THE ACTUAL AND POTENTIAL DIFFUSION OF MTIs

Some of the most interesting results of this research were found in the description of individual cases of actual and potential diffusion of MTI. In Chapter 6, some MTIs had diffused and a potential demand for greater diffusion of MTIs had been expressed. There was no reason not to believe from the hypotheses testing that any MTI, from any operating unit, had an equal chance of being diffused. Although many MTIs were considered potentially useful, few had actually diffused. This chapter presents some observations about the MTIs that did diffuse and those that did not diffuse but were considered potentially useful. The objective of the chapter is to better understand those influences that facilitated or inhibited the diffusion of MTIs between NOU and OOU. The chapter ends with a discussion of the opportunity costs to the research site of not converting more potentially useful MTIs into MTIs that are actually used.

This chapter is divided into three sections. First, cases of actual diffusion are presented. Second, reasons for non-diffusion are presented with examples. Finally, the potential for more MTI diffusion and its significance to improving operations within the research site, are discussed.

Cases of Actual Diffusion of MTIs

Eight observations were made of an MTI from an OOU diffusing to an NOU. Seven of these involved diffusion of an MTI to one NOU. One involved the diffusion of an MTI to two NOUs. For more details than are provided in this chapter on the technical nature of specific MTIs, the reader is referred to Appendices 1 and 2. The following are the MTIs that diffused.

CONTINUOUS POLYMER FEEDING SYSTEM

The continuous polymer feeding system documented in this research was developed and patented by an engineer in the mill department at Geco in Northern Ontario. The system fed and mixed a chemical used to separate waste from water prior to its discharge into the environment surrounding Geco property. The system was installed in March of 1981. The new system was built for $2,620 and eliminated the purchase of a $20,000 commercially available system which performed a similar function using different technology. The new system, compared to previous methods, reduced maintenance costs and chemical usage. It was also found to be more reliable and greatly improved the quality of the water discharged.

A manager in the mill department at the Horne division heard about the Geco MTI during a conversation with a Noranda employee in a staff function at the corporate head office in Toronto. The engineer responsible for water treatment at Horne was sent to Geco. In the fall of 1983, the Horne mill installed a modified version of the Geco continuous polymer feeding system. Only part of the Geco system was used because of differences in the processes between the two mills.

AIR NOZZLES FOR AERATORS

In the mill department at Mattabi, a modification was made to the aerator tanks to replace air drop pipes used to inject air into the water and crushed ore. Usually the pipes entered the tank from the top. Unfortunately, this arrangement resulted in the pipes getting blocked, resulting in downtime for the tanks and all other dependent tasks in the milling process. The modification replaced the pipes with a combination of a valve and nozzle installed in the bottom of the tank. This arrangement was not prone to blockage. The result was increased uptime, better mixing and lower maintenance costs.

Early in 1983, a mill foreman from Geco discovered the MTI during a visit to Mattabi mill on other business. The Geco foreman requested further information on the nozzles from Mattabi personnel. The MTI was manufactured and installed later that same year at Geco.

LIME SLAKING

The mill department at Matagami developed a new method of controlling the slaking of lime in 1982. Lime is mixed with water during a process called slaking which causes a reaction which in turn precipitates the metal from the crushed ore. If this reaction is not carefully controlled, using the correct proportions of lime and water, the reaction will be incomplete and recoverable metals will be lost. The MTI involved the addition of microprocessor controls to monitor the temperature of the reaction in order to determine the amount of lime and water required.

In the winter of 1984, the assistant concentrator superintendent at the Horne mill was keeping alert for new lime slaking procedures as he travelled to other mills within Noranda and mills on other mining companies' properties. He had heard from a friend at Matagami mill that they had a useful process. Technical details were supplied at a Canadian Mineral Processing Association seminar for the North Quebec region. In the spring of 1984, Horne mill adopted a modified version of the slaking system utilizing the process control devices but not the arrangement of tanks and other supporting equipment.

CABLEBOLT FEEDING DEVICE

In the spring of 1982, a project technician in the Brunswick mine developed an air-powered device to insert cablebolts into drill holes. Cablebolts are long, heavy, braided cables up to several metres in length, used to secure rock in the working areas underground. The device was found to be three times faster than the previous manual methods. The MTI eliminated the potential danger of serious back injury to miners lifting and pushing the cables into the holes above their heads.

In the winter of 1984, the superintendent of the Gaspe mine department was shopping around for a cablebolting system. His search activities consisted of reading technical journals and travelling across Quebec looking at operations at Noranda facilities as well as at other companies. On some of these occasions, he was accompanied by his chief engineer. Through the superintendent at the neighboring Brunswick mine, they contacted the project technician. Gaspe sent equipment operators and shift bosses to see the device in action, then purchased it through a mining supply company which had been licensed by Brunswick to sell the device. It was in regular use in 1985 at Gaspe.

CABLEBOLT CUTTING DEVICE

The project technician at Brunswick who invented the cablebolt feeding device also developed an explosive device for shearing cable bolts. Prior to this MTI, oxy-acetylene torches were used to cut the ends off cables left hanging from the workface after blasting. The manhandling of the heavy torch unit across broken rock was dangerous. The new device was a shaped charge of explosive which could be clipped to a cablebolt and when ignited by a distant operator, sheared the bolt with a concentrated blast. If a number of the devices were ignited at once, savings could be realized in set-up time compared to the old torch method. The device was first used in June of 1985 at Brunswick. Du Pont Chemicals of Canada manufactured the first prototypes used at Brunswick, then started manufacturing and marketing the MTI under DuPont's own product name, Deta-Cab. Du Pont in 1985 acknowledged Brunswick as the source of the idea but paid no royalty. Brunswick had no patent on the device.

In October 1985, a mine engineer at Gaspe was approached by a blast teshnician from Du Pont Chemicals. Du Pont had been a regular supplier of explosives to Gaspe in the past. He offered the Deta-Cab to the engineer as a new product from Du Pont. Gaspe was unaware when the researcher contacted management in late 1985 that the device had originated at Brunswick.

At the same time, the mine engineering department at Geco was also solicited by a Du Pont blast technician about purchasing Deta-Cab devices. Geco found the devices useful for removing rockbolts that were under pressure and which could potentially release suddenly on an oxy-acetylene torch operator, causing injury. Geco management were also unaware that Brunswick had been the source of the MTI.

ANFO-TOTE BAGS

In April 1984, the Geco mine department changed the way it handled explosives in its quarry operations. Prior to this MTI, quarry blasts were set up by loading 55-lb. bags of Anfo explosive by hand and funnel into drilled blast holes. Anfo is a dry powder explosive. With the assistance of supplier representatives from Dupont and C.I.L., woven plastic bags capable of carrying 2,000 lbs. of Anfo were prepared and filled by the supplier with Anfo.

The full bags were then suspended by a boom truck over the drill holes and poured. The new handling technique reduced the number of man-hours required for the task and the danger of back injury associated with carrying the 55-lb. bags of Anfo.

The Gaspe mine department had used a similar method in its open pit operations early in the 1970's, with the help of their regular explosives supplier at the time, C.I.L.. In 1980, Du Pont representatives helped Gaspe apply the technique in its underground operations. Both Geco and Gaspe were unaware of each other's applications of this materials handling system. The supplier had used experience from Gaspe and other mines to help develop the MTI used later at Geco.

MOBILE WASTE OIL TANK

Two welders from the Lyons Lake mine department constructed a waste disposal tank in October of 1984 that could be moved underground close to work areas where oil was being extracted from machinery. Prior to the use of the MTI, oil was often spilled on the floor, creating dangerous footing. The waste oil was shipped to the surface in old 45-gallon oil barrels. These barrels were awkward to handle and time-consuming to load for transportation. THe MTI was basically a large vented steel tank on wheels with funnel and drain attachments for easy loading and unloading of the oil. Two of the tanks were constructed in the mine shops for $370 each.

The mine maintenance foreman from the neighboring Mattabi mine saw the two tanks under construction at the Lyons Lake shops. He asked for and received one of the completed tanks for use at Mattabi.

Discussion of Actual MTI Diffusion

All eight observations of actual diffusion occurred as the result of an NOU or one of its suppliers discovering an MTI at an OOU. None of the eight observations occurred as a result of OOUs offering their MTIs to NOUs. An MTI was either "need pulled" by an NOU out of OOU, or adopted by a supplier for marketing. The OOU did not directly advertise or promote its own innovations. The continuous polymer feeding system and the lime slaking system were in the public domain. The feeding system had been patented and the lime slaking system had been presented at an industrial association seminar.

In five of the observations, the NOU made inquires of the OOU about an MTI. Inquiries in two of these observations originated from NOU personnel visiting an OOU's operations and by chance seeing an MTI in action. The diffusion of both the air nozzles and the waste oil tank resulted from visits involving supervisory staff from the NOU who noticed the MTIs during the course of other business. The other three observations involved managers from an NOU being put in contact with the appropriate people in an OOU interested in or experienced with a common concern. In the case of the polymer feeding system, a corporate staff employee referred the manager of the NOU to an OOU. The assistant concentrator superintendent of the NOU heard about the lime slaking system from a friend at the OOU. The superintendent of the NOU was referred by the superintendent of the OOU to the employee responsible for the cablebolting device.

The remaining three of the eight observations of actual diffusion resulted when suppliers informed NOUs about products they possessed and that had been used successfully at other Noranda operating units. The cablebolt cutting device diffused to two NOUs when the supplier promoted the sale of a commercial version of the MTI. The Anfo tote bag was the result of a supplier helping an OOU adapt a technique that had been developed for use earlier at an NOU.

This was the only observation in which an MTI suggested by an operating unit and therefore classified as its OOU, was later found to have its origins in an NOU's operations.

Although there are only eight observations of MTI diffusion from which to generalize, they do supply a number of interesting insights into how MTIs actually diffuse within a firm with multiple operating units. First, MTIs are "need pulled". Either an NOU actively searches for an MTI to satisfy a need, or a supplier markets an MTI to satisfy an NOU's needs. This is not surprising since operating units are not in the business of developing products for sale to other operating units. Second, contact between the management of different operating units and corporate head office is a potential conduit for information to create awareness of an MTI, possibly leading to its subsequent diffusion. Third, employees of one operating unit, if given the opportunity to observe other operating units, can identify useful MTIs that can be targeted for future use.

There was no apparent rule governing the length of time required for diffusion. The cablebolt cutting device took approximately three months from first use at Brunswick to later use at both Gaspe and Geco. At one extreme, the Anfo-tote bag technology had been used for more than ten years at Gaspe before the application at Geco. At another extreme, the mobile waste oil tank had diffused from Lyons Lake to Mattabi before the MTI had seen regular use at the OOU. The length of time to diffuse an MTI to various operating units may be predictable by the geographical distance between the OOU and the NOU. It is interesting that five of the eight observations occurred between operating units of the same geographic region. If the three observations of supplier involvement are removed, only the continuous polymer feeding system diffused between regions. Its diffusion took approximately 2.5 years.

The MTIs that actually diffused tended to require a minimum of physical adaptation of the OOU's design to be acceptable for use by the NOU. Only the continuous polymer feeding system and the lime slaking system were reported to have required any modification for adoption. In both cases, adapting an MTI involved adopting only part of the MTI. All other MTIs had an off-the-shelf portability which suggested that they could be sold to other operating units as patented products. The decision whether to adopt an MTI may be one of "take it as is" or leave it. Operating units may not be interested in making the effort to adapt MTIs to suit their operations.

MTIs That Did Not Diffuse

As noted in Chapter 6, 378 observations were recorded where NOUs were not using an OOU's MTI. For each of these observations, a NOU had indicated that a given MTI was not being used. In the majority of these observations, NOU personnel said that they had not beeh aware of the MTI's existence. In some observations, NOU personnel commented that they were aware of the technology involved in an MTI but were unaware of its successful application at the OOU. Once made aware of an MTI by the researcher, NOUs had two basic responses about those MTIs they were not actually using. In 63% of the observations of non-diffused MTIs, respondents indicated that NOUs could not or would not see any potential use for an MTI in their operations. Although not using an MTI, NOUs indicated that they could see its potential use in the near future in 33% of the observations. A remaining 4% of observations were unclassified as to whether the response was positive or negative to potential use.

MTIs Not Used And Not Potentially Useful

Three major reasons were given for not considering an MTI as potentially useful. NOUs saw no potential use for an

MTI 60.5% of the time because it was not technically compatible with their operations. They indicated 31.1% of the time that they had technology similar to the MTI already in place which was adequate for the task. NOUs were skeptical about the value of the MTI as the best approach to a problem or opportunity in their situation 8.4% of the time.

In most cases where the MTI was not technically compatible with an NOU's operations, there was no urgent need that would make the MTI useful. For example, drill hole dewatering was not useful to some mines because their underground operations were relatively dry. If a mine is "wet", drill holes get flooded with ground water which neutralizes the powdered blasting explosive poured down the hole.. Some MTIs were not useful because they were specific to minerals being processed. For example, not all mills could use the copper sulfate mixing system from Mattabi because not all mills processed zinc, which requires copper sulfate as a reagent in the floatation process. A number of responses of non-use for reasons of compatibility were based on the type and make of equipment. For instance, the brake compressor remount on the ST2B scoop trams at the Horne mines was necessary only for that model of scoop tram. The brake compressor, which helps stop the machine, was routinely damaged due to a design flaw particular to that make and model of machine. Not all mines had this make and model.

For those observations where respondents indicated that they had similar technology doing a similar function, NOUs often had different types or vintages of equipment that removed the need for an MTI. For example, the cappel remover for hoist cable maintenance at Mattabi was not required at some other mines because their skips had been designed to alleviate the problem that had necessitated the MTI at Mattabi. Some very similar MTIs had been innovated independently at the same time at two different operating units. For example, both Gaspe and Geco mines had developed new methods of drill hole dewatering so that cheaper explosives could be used more efficiently. Both mines had developed their approaches to suit specifics of their drilling techniques, such as hole length and diameter.

Some NOUs were skeptical about the merits of an MTI's use in their operations. A common remark about QMTIs from mines by other mines was that they were unsafe. For example, the modification of the seating of the scoop trams used at the Horne mines was considered by all the NOUs to be unsatisfactory because it projected the operator compartment beyond the chassis of the scoop tram, exposing, the operator to the danger of being crushed against a tunnel wall. In the case of the pipe handling device from Geco mine, some NOUs considered the air-powered lift vehicle to be an overly complicated approach to hoisting pipe overhead in a mine tunnel. Some NOUs were concerned about the effect of an MTI on working conditions, as in the case of a hot tank for cleaning mechanical parts. Some NOUs were apprehensive about the handling and disposal of the potentially toxic caustic soda used as the cleaning medium in the tank.

It should be noted that the reasons for not considering a given MTI potentially useful were not the same for all NOUs. An MTI was often unattractive to two NOUs for different reasons. The Deta-Cab device described earlier was perceived by some mines to be a labour-saving device while others saw it primarily as a means of doing a task more safely. Not all NOUs could decide whether they could potentially use an MTI. Some considered certain MTIs, such as the Zorbal hopper from Lyons Lake to be trivial and thus were ambivalent about whether they could or could not use the MTI.

There was a statistically significant difference between PMTIs and QMTIs in the reasons given for non-use of an MTI (Chi Square = 19.5, Sig.= .0002). PMTIs tended to be rejected 64.5% of the time because of operating system incompatibility, as opposed to 41.7% for QMTIs. In 32.1% of the cases, QMTIs were rejected because an NOU had a similar or alternative approach, as opposed to 27.8% for PMTIs. NOUs often had similar health and safety problems that were more homogeneous and well known across operating units. QMTIs were rejected 15.5% of the time because of dissatisfaction over the approach taken by the OOU, as opposed to 4.1% for PMTIs. NOUs were often more critical about practices that could risk health and safety. A possible interpretation of this result is that QMTIs were more easily understood from the video tape and written descriptions of MTIs. For PMTIs, respondents were reluctant to make any comment until they carefully examined the economics. Therefore, opinions about QMTIs were often expressed more strongly than those about PMTIs. There were no significant differences between mills and mines in their reasons for rejecting an MTI.

MTIs Not Used But Potentially Useful

NOUs indicated potential use of an MTI in 33% of the observations. Of these, 90.4% were unconditional in nature. Some NOUs suggested that an MTI could replace an existing piece of equipment or practice 6.4% of the time in the foreseeable future. In 1.6% of observations, NOUs indicated that an MTI could be useful in the near future when the NOU underwent changes to its operations. Other NOUs stated that an MTI was potentially useful, conditional on changes to certain unsatisfactory aspects of the MTI, 1.6 % of the time.

The number of NOUs that considered an MTI potentially useful varied. Using a weighted average, a mine MTI could potentially diffuse to 2.73 mines and a mill MTI to 2.68 mills. There was no significant difference between QMTIs and PMTIs in the potential number of operating units to which they could diffuse. Of the 73 MTIs used for this research, 60 (82.2%) could potentially be used by one of the other operating units participating in the research. This figure included MTIs that actually diffused but which could diffuse potentially even further.

Discussion of Actual and Potential MTI Diffusion

Only 17.8% of the MTIs sampled in this research were considered to be of no actual or potential use to one of the NOUs. Although only seven or 9.6% actually diffused there is a large potential for other MTIs to diffuse given the opportunity. Until made aware of the MTI by the researcher, NOUs had no opportunity to consider the question of whether they were using an MTI and whether they could potentially use it. From the findings in this chapter, a picture does emerge about the mechanics of MTI diffusion within a firm with multiple operating units.

In order for an MTI to diffuse, the NOU must be made aware of the MTI's existence. In this research, the initiative to create awareness was taken by the NOU and suppliers or by efforts such as this research. Indications are that potentially useful MTIs can be found, given thorough search activities by the potential user. The MTIs found to be useful will vary in their age and amount and type of benefits. The magnitude of the economic benefits may be secondary to the utility of the MTI in making an improvement to an NOU's operations in the area of QWL. Useful MTIs have to be drawn forth from people's memories before they are forgotten. The people who know about MTIs and/or innovate them will have to be contacted. A frequent comment made by employees of NOUs was that they did not know who to contact in an OOU even if they suspected that an MTI existed that was of potential use to them.

Given the diffusion of a few MTIs and the large potential for further diffusion, some consideration was given to whether realizing the potential was worth the effort. On average, an operating unit found one out of three MTIs of potential use. The same MTIs were not consistently picked by all operating units. Therefore it was difficult to calculate the average benefits per operating unit of translating potential to actual diffusion. A more valid and relevant accounting for the corporation as a whole was total benefits across all operating units. The next section presents this analysis.

Potential Benefits from MTI Diffusion To The Research Site

The operating units in Noranda that participated in this research had experienced an estimated $4.2 million in total net savings over the life of the 73 MTIs. These savings were achieved within individual OOUs with no diffusion to NOUs. No formal effort had been made by Noranda Corporation or individual operating units to diffuse these MTIs to all operating units where they could be potentially useful. An important question is whether it is worth management effort and firm resources to encourage more actual diffusion. A partial answer lies in estimating the potential net savings or revenues that could have been made if MTIs diffused to all potential users, in the context of this study.

While it is difficult to predict future benefits from MTI diffusion, an estimate can be made from the 73 MTIs used in this research and the NOU responses to them. Potentially, $11.6 million in net savings could have been realized by the 13 operating units used in this research if they had adopted all of the MTIs from other operating units that they considered potentially useful, soon after the MTI was innovated. This figure is based on the number of potential users for each MTI multiplied by that MTI's net savings over its life. In reality, even very lucrative MTIs would be expected to be delayed for at least small periods in their diffusion in the process of acquisition. The calculation of potential benefits is summarized in Appendix 5. The observations of actual MTI diffusion were not useful in this estimation. Three of the eight observations involved QMTIs. Another two were so recent in their diffusion that there was no accurate information on their performance. The remainder did not have detailed cost and benefit information.

The actual net savings to Noranda realized on MTI activity across its operations are understated by this research. Not all net savings for all MTIs were included in the estimates because of the lack of accurate accounting information available from the operating units involved in the research. As mentioned in Chapter 5, informal book-keeping and project management was the norm rather than the exception in innovating MTIs. An estimate of net savings from getting potentially useful MTIs actually diffused therefore is also probably understated. The cost savings due to avoiding the re-invention of the same or similar MTIs is not recorded. This research did not sample the total population of MTIs that were or had been in use. Only 13 operating units of Noranda's mining operations were used. The researcher was able to document only 73 MTIs, many of which were chosen as representative of a number of innovations on a short list selected by a fraction of the operating unit's total personnel. Given the time and access to all Noranda mining and milling operations and contact with a greater number of the employees in each operating unit, more MTIs would have been available. Even greater net savings could have been found.

Some potentially quantifiable benefits to operations were claimed by operating units but not accounted for in terms of dollar net savings. Production uptime and the recovery of metal were improved in both mines and mills by some of these innovations. Operating performance was improved by MTIs that allowed for better management of people and the process. As in the case of two of the MTIs that actually diffused, there were opportunities to sell the technology to other firms.

Significant improvements in QWL were achieved which were not quantifiable in economic terms. There was evidence that some MTIs that improved QWL simultaneously improved productivity and vice versa. Seventy-five percent of QMTIs were attributed with some productivity improvement. Thirty-six percent of PMTIs were attributed with some QWL benefits. This finding was not surprising since many of the MTIs involved improving labour productivity in areas where employees did not like to work because it was unsafe, unpleasant and/or inefficient. Not quantified were the long-term benefits to morale and employee relations which resulted from involving employees in innovations which improved their ability to perform and their working conditions.

Comments and Conclusions

The picture that emerges from this chapter of MTI diffusion within a firm has three major features. First, actual diffusion of MTIs does occur, usually as the result of potential users searching for MTIs. Second, there exists a large potential for diffusing more MTIs, given mechanisms by which information about MTIs can be exchanged between the originating operating unit (OOU) and non-originating operating units (NOU). Finally, there are significant potential benefits, at least for the research site in this thesis, to be gained from MTI diffusion. In the past, significant opportunity costs may have been paid by Noranda corporation as a whole in not realizing the full benefits of MTI activity through diffusion to all potential users.

CHAPTER 8

CONCLUSIONS AND IMPLICATIONS

The most interesting finding of this research was the support for the importance of the actual and potential diffusion of Minor Technical Improvements (MTIs) to the improvement of operations. Not only did MTIs improve operations in the individual operating units which developed them, but some actually were diffused to improve those of other operating units. Operating improvement came in the form of both productivity and quality of working life improvement. A large potential exists for even greater diffusion of MTIs among operating units of the research site.

These results were not predictable based on the existing literature on technological innovation, which suggested that minor innovation should remain specific to the local conditions in which it is innovated, if in fact it is even worth diffusing. The major implication for the study of the management of technological innovation is that the diffusion of MTIs within firms may be a more important contributor to productivity and QWL improvement than previously thought. Furthermore, there are opportunities for firms to successfully manage the diffusion of minor innovation. These opportunities may be attainable by firms with multiple operating units in a variety of possible industries, through effective and persistent communication between informed and knowledgeable people in the various operating units.

This concluding chapter contains a summary of the major findings. The implications of the research for the study of the diffusion of technological innovation are then briefly presented. The implications for management follow. Finally, opportunities for further research are suggested.

Summary of Major Findings About Actual and Potential Diffusion

Of the 73 Minor Technical Improvements (MTIs) examined in this research, seven MTIs or 9.6% diffused from the Originating Operating Unit (OOU) to a Non-originating Operating Unit (NOU). One of these MTIs diffused to two other NOU. Sixty MTIs or 83% were considered to be potentially useful and thus potentially diffusable by at least one NOU. These included the seven MTIs that had already actually diffused to some NOUs. On a weighted average, 2.68 out of six mills and 2.73 out of seven mines indicated that they could potentially use a given MTI.

In all eight observations, the efforts of NOUs and people outside the OOU initiated communication leading to diffusion. The OOUs played a relatively passive role in the actual diffusion of their own MTI. In five of the observations, the NOU made inquiries of the OOU about an MTI. Inquiries originated in three observations from NOU personnel familiar with an OOU's operations. In the other two observations, inquiries by NOU management were prompted by information from staff at corporate head office and by the chance observation of an NOU supervisor while visiting an OOU. Following the inquiries, the NOU in four of these observations adapted the OOU's MTI to its needs, and in one observation was referred to a supplier for the purchase of the MTI. The remaining three of the eight observations of actual diffusion were the result of suppliers informing NOUs about products they possessed that had been used successfully at other Noranda operating units. Two of these observations of diffusion involved the same MTI. The other observation involved the diffusion of an MTI that had been developed by the OOU, based on a supplier's product.

Examination of the details of the eight observations of actual diffusion highlights two important factors that facilitated MTI diffusion. First, personal contact between the potential user operating unit and the innovating operating unit was effective. Contact was made either directly or through an intermediary such as a supplier and/or corporate staff person. There had to be some sort of "people to people" exchange of information as opposed to a more passive communication, such as a technical report. Second, suppliers of equipment and materials were important conduits of MTI information. Suppliers often served more than one operating unit of the same firm. Three observations involved suppliers manufacturing MTIs from Noranda operating units and marketing them to other Noranda operating units. In two of these observations, the adopting operating units were unaware that another Noranda operating unit had been the source of the MTI.

There was no statistical support for the hypothesis that PMTIs were potentially more diffusable than QMTIs. Four of the seven MTIs that were actually diffused were from mining operating units; of these, two were Productivity-improving MTIs (PMTIs), and two were Quality of Work Life- improving MTIs (QMTIs). The other three MTIs were from milling operating units and all were PMTIs.

In situations where NOUs stated that an MTI had no potential for diffusion, three major reasons were given.

Sixty-one percent of the time NOUs rejected an MTI as not technically compatible with their operations. They did not have a similar problem or opportunity in their production process that could be addressed by the MTI. Thirty-one percent of the time they stated that they had similar technology already in place. In a number of these cases, NOUs had independently innovated their own approach to a problem or opportunity which was similar in design or effect to an OOU's MTI. Eight percent of the time they were skeptical about the value of the MTI as the best approach. QMTIs when compared to PMTIs were more likely to be considered unsatisfactory. This was due partly to different perceptions among operating units about what was or was not a safe operating procedure.

Most observations of actual and potential diffusion between OOUs and NOUs were not found to be predictable by attributes commonly used to describe innovations and mining and milling operating units. These attributes, taken from the traditional economic and sociology literature on the diffusion of technological innovation, were not found to be significant except in one aspect. Mines and mills were sufficiently dissimilar in how employees in each perceived the other's technology such that mill MTIs did not diffuse nor were they considered potentially diffusable to mines, and vice versa. Surprisingly, the physical distance between OOUs and NOUs and their relationship to each other in the corporate organizational structure did not appear to be significant as explanations for observations of actual or potential diffusion.

Rogers' work on the diffusion of innovation is partially supported in this research in that communication is important to diffusion. Not supported is the proposition that the greater the similarity between innovator and potential adopter, the greater the communication, and thus the higher the likelihood of diffusion. Predicting actual or potential use of an MTI based on general, generic descriptive variables about the operating unit and/or MTI was not possible for the range of variables and the research site used in this research.

This research does give some indications that the medium of communication may be important to MTI diffusion. In Chapter 6, when the MTIs documented and communicated by video tape were statistically analyzed separately from those in writing, differing results were found. The use of video tape may make a significant impact on the success of efforts to communicate MTIs. Operating unit group members frequently commented on the richness of the information about the MTI provided on the video tape.

Theoretical Implications

The research findings have a number of implications for the study of innovation in general and the diffusion of minor innovation within firms, in specific. The major implications are:

1) Diffusion of minor innovations actually occurs within a firm. There is the potential for even greater diffusion.

2) Awareness of MTIs, across operating units, is an important prerequisite to MTI diffusion.

3) Increased diffusion between operating units may depend on improving the communication of potentially useful MTIs between operating units.

The Diffusability of Minor Innovation

Within Firms

The actual diffusion of MTIs within a firm documented in this research gives some evidence that minor technological innovations can move from OOUs to NOUs. The large potential for diffusion between OOUs and NOUs suggests actual diffusion may in the future occur on an even larger scale in this firm. These findings further suggest that technology of the scale and type represented by MTIs may not be as specific to or localized in the OOU as previously thought.

More than 33% of the time, an operating unit found an MTI potentially useful after being made aware of its existence by the video tapes and written documentation used for the research. This may amount to a significant number of MTIs over time given that MTIs are being conceived frequently and routinely across operating units of a firm. A rate of adoption of 33% of MTIs from a steady stream of available MTIs may be quite significant to continued operating improvement. It should be noted that approximately 30% of those NOUs which responded that they could not potentially use an MTI also stated that they innovated a similar MTI. These incidents may represent examples of "reinventing the wheel". Such activities can be interpreted as further evidence that the technology is needed, but that there is no mechanism for quick and consistent diffusion of information about MTIs.

Awareness of MTIs

The research findings suggest that the largest barrier to diffusion of MTIs may be the lack of awareness among NOUs of what MTIs are available. There is a large difference in the number of MTIs that were considered potentially useful and those that were actually used. Most operating unit groups were familiar with the general nature of production in other operating units, but were not familiar with particular MTIs. Within the research site there was no formal means of disseminating information about MTIs evenly and consistently among operating units. It was only because of persistent searching of potential users or an intermediary acting on the user's behalf, that potentially useful MTIs were discovered and diffused. The search activities were triggered by the needs of the potential user.

The question of what motivates some units to innovate within their own operating unit or to satisfy an operating need by contacting another operating unit is complex. One possible inhibitor of contact with other operating units is a manifestation of Not-Made-Here attitudes. Another is the lack of time and money to engage in search activity. Another possible answer was implied during the research field work by the comments of some of the participants. The personnel of one operating unit often had preconceived ideas about another operating unit's operations and management, which inhibited or encouraged contact between the units. Personnel from one mine tended to view another mine as being distinct from their own, often noting for example, size, geology, mining techniques and stage of development as different. Mill personnel were quick to note the differences in other mills in terms of size, minerals processed and type and configuration of equipment. The tendency by an operating unit's personnel to generalize the differences between operating units in some technologies to all technologies, may have undermined the motivation to seek out specific areas in another operating unit's operations where a potentially useful MTI may have existed.

Communication of MTIs

One of the more promising areas for theoretical development in the diffusion of MTIs within firms lies in better defining the nature of the personal contact required to communicate awareness and detailed information about an MTI. Rogers' work suggests that the degree of similarity between innovator and potential user determines whether there will be successful communication leading to diffusion of a useful innovation. Similarity as measured by variables operationalized at the organizational level (operating unit) did not seem to influence actual or potential diffusion of MTIs in this research. Similarity measured at a less aggregated level such as the department or individual, may be more useful. For example, if two engineers or production supervisors from two different operating units have similar specific operating concerns, they will be more likely to have productive exchanges about useful MTI-type innovations.

Since MTIs tend to address very specific operating needs which are not a major concern of the whole operating unit, communication between management of two operating units may not include information about MTIs. Management also may not be aware of all MTIs that have been developed in their operating units or the specific needs which could be resolved by an inquiry of another operating unit. More useful information about MTIs may pass between two production supervisors from different operating units than between the managers they report to. As indicated in Chapter 5, supervisors had an important role in the definition of needs for innovation and the development of MTIs. Supervisors and other technical people, such as instrument technicians, mechanics and engineers, were often the operating unit's repository of the nuts and bolts details about the production process from which MTIs are effectively innovated (e.g., the idiosyncracies of various makes and models of equipment). These ~~may~~ be the people who should talk or visit each other on a regular basis. In reality, the production supervisor or other technically capable people lower down in the organizational structure of the operating unit may never get a chance to communicate with people in other operating units regularly. Their responsibilities are usually focused on the specific day to day tasks of keeping the production system out of trouble. Travel and communication by telephone and correspondence between operating units tend to be the activities of upper management.

Managerial Implications For The Research Site

This thesis has some specific managerial implications for the research site, Noranda. As will be indicated in the next section, these implications are not restricted to the research site and its industry. The major managerial implications for Noranda are as follows:

1) Significant benefits to operations across Noranda were achieved by MTI activity. Greater benefits might have been achieved by diffusion of MTIs to all operating units that could potentially use them.

2) MTI activity benefited operations across the reasearch site not only in terms of cost savings and productivity improvement but also in the improvement of the quality of work life.

3) In order to fully realize the benefits of MTI diffusion, a network of technological gatekeepers must be identified across the operating units and able to maintain effective communications with each other. Individuals and organizations within and outside the corporation capable of crossing organizational boundaries between operating units should also be identified.

4) MTI diffusion can be achieved at the initiative of individual operating units or through programs directed by the corporate headoffice. Noranda may have to make a strategic choice of the method that will best serve the company.

Actual and Potential Benefits of MTIs and Their Diffusion to the Research Site

The research site, Noranda Corporation, has experienced $4.2 million in net savings, estimated from the 68.5% of the 73 MTIs sampled which had usable economic data available. This sum was realized over the life of the MTIs, which averaged less than two years. These MTIs were continuing to accrue benefit for Noranda when this dissertation was written. Given the potential for diffusing more than 80% of these MTIs to at least two other NOUs, these net savings could have been significantly greater. If each MTI was diffused after first use from the OOU to all NOUs which considered it potentially useful, then additional net savings of approximately $11.6 million may have been realized. Unfortunately, except for the seven MTIs that actually did diffuse, the benefits from individual MTIs were realized only in the OOU.

The actual net savings experienced by the research site across all its operating units, attributable to MTI activity, are understated by this research. Not all net savings for all MTIs were included in the estimates because of the lack of accurate accounting information available from the operating units involved in the research. An estimate of net savings from the actual diffusion of potentially useful MTIs was therefore also understated. The cost saving due to avoiding the re-invention of the same or a similar MTI is not recorded. This research did not sample the total population of MTIs that were or had been in use. Only 13 operating units of Noranda's mining operations were used in the study. The researcher was able to document only 73 MTIs, many of which were chosen as representative of a number of innovations on a short list selected by a fraction of the operating unit's total personnel. Given the time, access to all Noranda mining and milling operations and contact with a greater number of the employees in each operating unit, more MTIs would have been available. Even greater net savings would have been found.

Quality of Working Life and Other Benefits To the Research Site

Significant improvements in QWL were achieved which were not quantifiable in economic terms but were actually diffused and potentially useful to NOUs. There was evidence that some MTIs not only improved QWL but simultaneously improved productivity, and vice versa. Seventy-five percent of QMTIs were attributed with some productivity improvement benefits. Thirty-six percent of PMTIs were attributed with some QWL improvement benefits. This finding was not surprising since many of the MTIs involved improving labour productivity in areas where employees did not like to work because it was unsafe, unpleasant and/or the job was not designed for efficiency. Not quantified were the long-term benefits to morale and employee relations of involving employees in innovations which improved their ability to perform and their working conditions.

Some potentially quantifiable benefits to operations were claimed by operating units but not accounted for in terms of dollar net savings. Production uptime and the recovery of metal were improved in both mines and mills by some of these innovations. Operating performance was improved by MTIs that allowed for better management of people and the process. As in the case of two of the MTIs that did diffuse, there exists the possibility that technology that can be used by other operating units within the firm can also be sold to other firms.

Improving the Diffusion of MTIs

The managerial task for fully realizing the benefits of MTI diffusion involves creating a network of technological gatekeepers across the operating units of the firm. MTIs buried in OOUs have to be drawn out, together with the people responsible for them and communicated to people in

NOUs with the needs and ability to recognize their value. As indicated in the research, these people need not be management. More than half the MTIs were innovated by hourly rated employees, tradesmen and supervisors. These people were in a position to innovate due to their intimate experience with the day-to-day operating problems and opportunities of the production process. This insight could be directed towards evaluating the adoption of other operating units' MTIs as opposed to innovating their own unique MTI. The engineering department need not be the exclusive repository of technological know-how; an operating manager might consider the training and delegation of responsibility for acting as operating unit technological gatekeeper to people such as supervisors or even hourly rated people.

In some operating units within Noranda there was greater involvement of employees in planning and implementing innovation. Employees such as supervisors in some operating units had been allowed to attend mining conferences and visit other operating units and mining companies. Noranda adopted formal employee involvement programs across the firm in the early 1980's. These had begun the process of routing information about production process performance and the technology available to affect it, to lower levels in the organizational structure of individual operating units.

The operating manager responsible for a number of operating units can encourage MTI diffusion personally and/or through subordinates, by effectively utilizing existing channels and developing new channels of communication within the company. A number of channels for disseminating information between operating units within a firm were noted during the course of the research. Using the following channels to their full potential across all operating units may facilitate MTI diffusion.

Personnel transfers between operating units.

Management and employee visits to other operating units.

Newsletters from different operating units.

Engineering reports.

Meetings and publications of industrial Associations.

Government programs aimed at technological transfer.

Suppliers.

Corporate staff.

Consultants.

Two of these means Noranda personnel mentioned frequently as being useful in developing effective channels for the communication of technical information. First, the transfer of technical personnel between operating units provided a "window" through which two operating units might compare operations and swap technology. The transferred employee brought not only the experiences of his or her old operating unit, but also the contacts in that operating unit for future reference. It was Noranda's corporate policy to encourage this activity as a means of developing and broadening the range of opportunities for the careers of its employees. Second, the visits of management and employees to other operating units had resulted in ideas and technical information being carried back to the home operating unit. Some managers had made a point of bringing experienced supervisors and technical people with them on visits to other operating units, with instructions to "wander around" looking for useful ideas.

A third possible means of diffusing information about MTIs, suggested from observation during the field work, was simply to have each operating unit subscribe to the other operating unit's newsletter. All operating units in the study were supplied with a local company newsletter of some sort. These publications were found to frequently recognize the inventions of employees as the result of suggestion plans or cost control programs, as well as solutions found by employee groups formed to deal with operating problems. The editors of the newsletters may be useful contact people at each operating unit for MTI information.

A more active strategy to encourage full diffusion of MTIs within Noranda may be to appoint individuals as official boundary spanners. These individuals would be responsible for crossing operating unit and divisional organizational boundaries to bring OOUs and NOUs together. In documenting MTIs on video tape and in writing, the researcher performed this boundary spanning role, opened up channels of communication and created awareness. This activity could be repeated regularly by company employees. The designation of an employee to oversee and act as a channel for information about MTIs at each operating unit or from a corporate staff position may be useful.

Another potential boundary spanner that was noted in the research was suppliers. In Chapter 5, 19% of the 73 MTIs in this study were found to have involved OOUs making major purchases of new equipment or methods from suppliers. Some suppliers were observed selling products that had originated at a Noranda operating unit to other Noranda operating units and competitors. Whether supplier involvement in these cases was a net benefit to Noranda was debatable. On one hand, supplier involvement assisted in the innovation of MTIs and their diffusion to other Noranda operating units. On the other, the competitive operating advantage of possessing a unique piece of useful technology was lost in its diffusion to potential competitors in the mining industry. In two incidences, the people credited as the inventors of an MTI thought that the supplier had manufactured and marketed a product based on their design without their or Noranda's permission.

Responsibility for Encouraging MTI Diffusion

In the past, MTIs have not diffused as extensively as they could have at Noranda. If the benefits of MTIs are to be diffused to all operating units, who will make the effort to create awareness across operating units of available MTIs? The research has documented no centrally coordinated effort to diffuse MTIs within Noranda. MTI diffusion to date has depended on the motivation of NOUs and suppliers. The Noranda Research Center attempted to diffuse its own inventions of major, state of the art, process technology. It had not been officially involved in the diffusion of minor innovation. Certain managers in the corporate head office had been effective in transferring operating changes from one operating unit to another. These had usually been larger, higher profile projects.

In the future, two major strategies are discernible for initiating MTI diffusion at Noranda. First, let individual operating units take the initiative in searching for MTIs and disseminating information about their own MTIs.

Corporate staff may act as a clearinghouse for information. Second, have corporate staff or a third party, such as a consultant, take the initiative to search out MTIs and place them in other operating units.

The success and failure of either strategy to diffuse more MTIs is difficult to predict without a consideration of the corporate culture at Noranda and its competitive environment. As mentioned in Chapter 4, Noranda Corporation has given significant autonomy to the managers responsible for individual operating units and properties. This is perceived by Noranda management and employees as an attractive feature of Noranda's corporate culture. If programs to diffuse MTIs are pushed by corporate staff, these efforts may be met with resistance. On the other hand, if there is no central coordination, the status quo documented in this thesis may be maintained. Past experience with similar corporate-wide initiatives such as employee involvement, has suggested that individual implementation by operating units tends to be uneven in timing and operationalization. Given the potential benefits of diffusion, or alternatively, the opportunity costs of delaying the diffusion of MTIs, a company-wide initiative by corporate management to create awareness of the potential for MTI diffusion is an important first step. This effort should be followed soon after by pointed inquiries by corporate superiors to operating unit management as to their degree of success in implementing the MTIs available from other operating units.

Managerial Implications for MTIs Diffusion Within Other Firms With Multiple Operating Units

The study of the diffusion of minor technological innovations within firms with multiple operating units represents an opportunity for research into an area of practical value to operating managers. This thesis research has been a limited venture into this underdeveloped area. Only one firm from one industry has been used. Although Noranda is a large firm in an important Canadian industry, the findings can be better generalized with further studies in other firms, in other industries.

Two major considerations are important in generalizing the experience and implications of MTI diffusion within Noranda to other firms with multiple operating units. First, firms in other industries may have greater, fewer or different opportunities for MTI diffusion than the research site. Noranda and other firms in the mining industry are considered to be conservative in their approach to management, relative to other sectors of the economy. This partially reflects the need for a management style geared to maximizing the long-term return on assets tied up in a mining property. Capacity must be fully utilized and costs controlled. The rate of major technological change in these circumstances is relatively slow. Under these conditions, a long period of minor innovation is possible and desirable. In other industries where the management style is more entrepeneurial and the rate of major technological change is faster, there may be less time for minor innovations. The source of minor innovation and thus the technological gatekeeper, role may shift from production employees as in the case of mining, to project specialists or process engineers.

The second major consideration about generalizing the Noranda experience with MTI diffusion is that firms in other industries may have more homogeneous operating units. As most mining people will testify, no two mines are alike. Operations in different facilities of the same company in manufacturing or services may be more standardized, thus sharing more common problems and opportunities for improvement with MTIs. For example, a minor process innovation in one of the many units of the MacDonalds hamburger empire might be highly likely to be used by other units because of the highly standardized operations from unit to unit. The total benefits to the corporation, in the MacDonalds example, would be multiplied across many operating units.

The concept of MTI diffusion within firms may be extended beyond the current research to at least three other management situations.

1) Operating environments requiring both process and product innovation.

2) Start up of new facilities.

3) Technological transfer in multinational firms.

MTI Diffusion of Product and Process Innovation

Conceivably, MTIs could also be minor technical improvements in the products produced by a firm. Product MTIs might improve the quality of the product or its ability to be manufactured. Industries such as mining and other primary resource industries such as forest products tend to be process-oriented. The product is a standardized commodity with little differentiation between firms. The focus of innovation is on improving the productivity of the process. As the operating environment shifts to one emphasizing product customization accompanied by flexibility in the production process to accommodate this variety, product-oriented MTIs may become more important.

MTI Diffusion and New Facility Start-Up

The advantages of MTI diffusion within firms are not restricted to firms with well established facilities producing at near full capacity. The diffusion of the best ideas from established operating units in a firm can be used to improve the productivity of start-up in new facilities. The experiences from other operating units in the firm may be transferable to the new facility, leading to a more rapid progress towards a steady state of high productivity. Experimentation from the new facility may be fed back to older facilities.

Technological Transfer in Multinational Firms

The diffusion of MTI innovations is relevant to the growing international scope of the study of operations management. In the past, studies of the diffusion of technological innovation were conducted by economists and sociologists at the level of economies and industries. In the 1980's, the breadth of operations in many large corporations makes such studies relevant at the level of the firm. This may be especially true for firms with multiple operating units spread around the world. As Canadian and American firms move towards greater involvement in world markets, technological transfer within firms with holdings in other countries will be a feature of operations management worthy of study.

Further Research

One of the major contributions of this thesis to the study of operations management is to highlight the practical benefits for operating improvement of nurturing continuous innovation, then diffusing it fully to all parts of the firm. One obvious direction for further research on MTI diffusion is to replicate this thesis in firms in other industries and situations as mentioned above. Another direction is to progress towards giving more detailed advice to operating managers about how they can achieve the benefits of MTI diffusion. Some suggestions are made for further research with this latter direction in mind.

The most interesting and immediate further research coming out of this thesis would be a follow-up study within Noranda. The study would entail revisiting the 13 operating units used in the research to find out how many of the MTIs considered potentially useful to NOUs in October 1985 were subsequently diffused. Predictably, not all will be diffused, for a number of reasons. These reasons may reflect technical incompatibility or certain organizational barriers. More important, the follow-up would measure the impact of the researcher s intervention into the operating routine of the units and whether such interventions should be repeated to further MTI diffusion.

Increasing MTI diffusion may be largely a function of how information about MTIs is communicated. Two mediums of communication were used in this research to create awareness of MTIs; namely, video taped segments of MTIs and written descriptions of MTIs. Determining which medium is more effective in assisting potential users in making decisions about whether to use a given MTI would be useful further research.

A unit's decision to search for and adopt MTIs from other operating units or firms (suppliers) as an alternative to innovating their own MTIs, is analogous to a "make or buy" decision. The process by which this decision is made would provide an interesting study. Some factors, loosely called not-made-here syndrome, may induce operating units to re-invent the wheel rather than look beyond their own immediate organization. A large part of Rogers model of the diffusion of innovation is based on the importance of information availablility to reducing the potential adopter's uncertainty thus minimizing the perceived riskiness of trying something new. If this is so, then it is important to identify the key pieces of information needed for a decision to adopt an MTI, and how they are attainable.

Conclusion

Diffusing Minor Technical Improvements to all potential users in other operating units offers significant opportunities to increase productivity and QWL in a company such as Noranda. When a sample of 73 MTIs were presented to 13 operating units, 60 of the innovations were considered potentially useful by at least one other unit. Without the intervention of the researcher, only seven of the 60 MTIs had actually been used by another operating unit. The difference between the number of MTIs that actually diffused and what potentially could diffuse represents a substantial opportunity cost for the company. Given a higher level of awareness among operating units through communication such as that done during the researcher's field study, this opportunity cost might be reduced and operating improvement progressed.

The literature on the diffusion of technological innovation has devoted scant attention to the diffusion of minor innovation within firms, from a management perspective. This thesis makes three important points on this subject. First, minor innovation is sufficiently generalizable in its use that it does diffuse between operating units of a firm. Second, MTI diffusion within firms can significantly improve operations not only in terms of cost savings and productivity but also in the quality of work life for employees. Third, the magnitude of the improvements possible is sufficient to merit management attention. The subject therefore warrants acknowledgement in the literature and further study by management researchers.

For operations managers, the positive indications from the research are that there is a resource of employee innovativeness available in-house to improve operations. There are synergistic benefits in firms with multiple operating units for operating improvement through greater MTI diffusion. Creating corporate-wide awareness of the opportunities available for operating improvement through methods such as those used in this research is a positive step towards greater diffusion of Minor Technical Improvements.

APPENDIX 1

DESCRIPTION OF THE VIDEO TAPED MTIs

The following transcript is the narration that accompanied the visual presentation of the MTIs that were video taped. Each segment is titled using the name most commonly used for the MTIs. Beside each name is operating unit of origin(OOU). Each segment of narration is presented in the order that it appeared in the actual presentation to the NOUs. This section begins with a listing of the MTIs, their OOU and type. (e.g.; PMTIs or QMTIs) Each of the 13 operating units contributed 2 MTIs except Horne mines which had 6: 2 MTIs from each of its 3 mining operations at Mines Gallen, Chadbourne and Remnor. Gaspe mill contributed only one MTI.

Listing of Video Taped MTIs

1) Pipe Handling Device (Geco Mine) **
2) NaHs Feeder Modification (Gaspe Mill)**
3) Remote Graphic X - Ray Analysis (Horne Mill)**
4) Concrete Transportation Car (Geco Mine)*
5) Man/Equipment Basket For Scoop Tram (Gaspe Mine)**
6) Lubricated Lantern Ring in Cyclone Chute (Horne Mill)*
7) Hot Tank For Cleaning Mechanical Parts (Lyons Lake Mine)*
8) Safety Breaking Device For Large Trucks (Gaspe Mill)**
9) Brake Compressor Remount on ST2B (Horne Mine)*
10) Continuous Polymer Feeding System (Geco Mill)*
11) Noise Suppression Package on Scoop Tram (Brunswick Mine)**
12) Modification of Seating on Scoop Tram (Horne Mines)**
13) Bulk Cyanide Handling and Mixing System (Geco Mill)**
14) Friction Washer for Screening Support (Brunswick Mine)*
15) Screening of Ore to Avoid Bin Freezing (Horne Mine)*
16) Mobile Waste Oil Tank (Lyons Lake Mine)**
17) Earthwork Supports For Tailing Pipes (Brunswick Mill)*
18) Computerization of Clerical Duties (Horne Mines)**
19) Cappel Remover For Skip (Mattabi Mine)**
20) Radio Headsets For Crane Operations (Brunswick Mill)**
21) Battery Charger for Remote Scoop Tram Transmitters (Horne Mine)*
22) Rock Breaker Setup Modifications (Mattabi Mine) *
23) BBC - 120 Drill Modifications (Matagami Mine)*
24) Smoke Detection on Ventillation for Mine (Horne Mines)**
25) Copper Sulfate Mixing System (Mattabi Mill)*

26) Production Blast Hole Caseing Collars (Matagami Mine)*
27) Dust Collector Over Slot Feeder (Mattabi Mill)**
28) Sulfur Dioxide Conditioner (Matagami Mill)*
29) Drill Hole Dewatering (Gaspe Mine)*
30) Slurry Screen for Pressure Filter Feed (Matagami Mill)*

* = PMTI   ** = QMTI

1) Pipe Handling Device (Geco Mine)

This MTI is called a pipe lifting device. It was designed at the request of the pipefitters because they had difficulty installing 6" pipe in the back. We used to install pipe by lifting it on our shoulders because of the awkwardness of using chain blocks and other types of lifting apparatus. We had one other such device which was operated by a hand wrench, it was very heavy and large and slow and had to be moved upwards and downwards on the track by hand.

The new device which you now see added safety and efficiency to the operation. It also eliminates the possibility of back and strain injuries. We had an existing backhoe on the property and we designed the arm and saddle at the end of the boom which lifts the pipe up to the hangar by pneumatics, thus eliminating the manual lifting of pipe.

At one time we could manually take down and put up 6-8, 10' lengths per shift with the pipe lifting device. We were able to take down and install 20-25 lengths per shift.

2) NaHs Feeder Modification (Gaspe Mill)

This device is used at our place to feed a chemical reagent called sodium- hydrosulphite. We feed this chemical reagent into our metal circuit. It is a very simple thing, it's mainly a plastic tube in which we send some solution of that reagent. Some of the solution comes in and it goes out by that tube by gravity. Here you have a special device that we had several months ago in order to improve the operation, and I will explain what it is. The problem we had several months ago was that when this tube was emptying itself by gravity, it was getting empty through a small line, three-quarters of an inch in diameter line, and it seemed that it created some negative pressure inside the feeder, and it prevented eventually the flow of the solution. The solution didn't want to come out any more. So operators had a lot of problems with this device. They had to dismantle the apparatus at least once every shift and it was creating problems so we added thi small device underneath it. It s a tank, a steel tank so as to avoid this negative pressure. The tube passing through gets empty into that small tank underneath and you have some kind of relief on top that allows the air to go out and then from this steel tank the solution will go into the small line. We don't have any more problems. So, through that modification we improved the control of the addition of that reagent and it helps improve the metallurgy of the metal circuit because of a lack or too much of that reagent that can really impair the results.

3) Remote Graphic X - Ray Analysis (Horne Mill)

This is something we did on our analysis x-ray system. We analyzed six streams simultaneously. This is an actual slurry cell with the radioactive source. This is the only means we had of looking at the results of our acids on a printer terminal. Operators had difficulty in establishing a trend. There is an actual printout every ten minutes. We decided to purchase a graphic terminal to help the operators see the trends of operation by visual graphics. This graphic terminal shows the six streams with the acids and 100% solids. We also purchased remote terminals for installation in the plant so operators would not have to run into the control room every time an assay came out. This is the first remote screen on the operator's floor showing the same graphics as the main terminal.

This is our second remote terminal installed in the metallurgist's office where he can see instantaneously the results of x-ray analysis.

4) Concrete Transportation Car (Geco Mine)

We used to pail all our cement out of one ton side-dump cars using three men. We pour about 2500 cars a year. This new cement car was devised by a group of employees. This car was devised because of problem with the old method we use before. By devising this new car we were looking at cost cutting and a safer way to do the job. (Some features were;)

1. Cost cutting - one man less.
2. Faster pour to save time.
3. More cars handled in one shift.
4. Cut down on back injuries.
5. Safer all the way around.
6. Easier to get people to pour cement, do not have to pick certain people all the time.

5) Man/Equipment Basket For Scoop Tram (Gaspe Mine)

In the early 1980s we started to drive some medium-sized stopes. Medium-size 10 x 16 or 10 x 18 foot stopes instead of the 9 x 9 or 18 x 24 kind. What we did, we took the idea from one competitor to install a platform or a basket in the bucket of scoop tram. In using the basket what we wanted to dowas prevent the guy from walking over the muck pile which was very dangerous. Also we wanted the guy to have a better access for scaling, also better access for dealing with bolting. The way that the basket is set up it is mounted on two main beams and we have a big pin that goes through both beams and also the side of the buckets. We got also a safety lock on each side of the bucket that prevents the pin from slipping out of it. In using this basket we have been able to achieve a much better job on bolting and scaling. It was done safer and one thing we must be careful with is that the overall advance is not too much. By doing so the scaler will be in the unsafe portion of the stope.

6) Lubricated Lantern Ring in Cyclone Chute (Horne Mill)

We replaced the chute feeding the ball mill between the conveyor and the feed throat of the ball mill. We were using a rubber chute before. Now we are using a metal chute with a lantern ring with water to lubricate it. The rubber does not burn out and we find out that the metal is very efficient. We have less down time, and if we have any problem we can just change a bottom elbow. We don't have to change the whole chute every time. It's much easier and much faster to change just the bottom piece. So it saves a lot on the clean up because before we had to have a man clean up every day and that was a lot of hard work. That chute was designed by our own mechanic crew and we rubber lined it at the same time. We are using it now across all our primary ball mill with very good results.

7) Hot Tank For Cleaning Mechanical Parts (Lyons Lake Mine)

The hot tank. In the component rebuilt shop we have this hot tank, which we use to clean parts; engine parts, transmissions, differential housing and also small parts. We put them in the basket and we just put them right in the tank and there we have water and caustic soda together. With the help of a meter on the side of the tank, it tells us if we have enough caustic soda in there or not. Also we have a temperature gauge, which indicates whether the solution is hot enough. Temperature ranges from 150 - 180. Also there is an air intake at the bottom of the tank which circulates the solution inside the tank when we have parts in there. It does a better job of cleaning when the water and the solution is being circulated. At the back of the tank there, we are able to see where the heating element had been put in, also the electrical connections. Here's another view of the electrical connection in there; a close up of it. On this side you see the air cylinder which activates the door to open the door and it's also very safe because as long as there is air in the cylinder the door will not come down, it's pretty heavy. On the inside here, you can see the bottom of the tank and there's this the element at the far end. Other than doing an excellent job in cleaning the parts it also was a very good at saving time. We saved a lot of money, a lot of hours.

8) Safety Breaking Device For Large Trucks (Gaspe Mill)

This is a safety brake device that we have built to install in our tractor- trailers. The ones that we use to haul sulfuric acid from the plant to where it is delivered. We used to have a lot of problems into the hills, so we decided that we had to do something to try and prevent those accidents. We had bought a few other types of brake device but they were not good to us - so this is what we came up to. It was designed and made at our place and it's made out of heavy material from one quarter to three-eighths steel and those brake shoes that you see. The wheel comes up on it and grips into the asphalt or into the ice to keep the tractor-trailer from sliding back. It would save us a lot of money and probably save somebody's life. So we did install the units and from the experience that we had with them for the couple of years that we had them on we did save at least two or three units from sliding of the road and spilling acid.

It's a very simple machine to operate, as it's filled with air. As soon as you release your air, your brake shoes falls to the surface to the ground and you let your tractor-trailer back on it and this will hold you in position for as long as you want to stay there.

9) Brake Compressor Remount on ST2B (Horne Mill)

We are looking at the modification of an ST2B Scoop Tramp using an F6L9-12 engine. The modification mounted the compressor's support off the engine and moved it on to the mainframe of the scoop tramp. The problem that we were having with this compressor was that on rough roads or due to jarring effects of the machine in motion the front cover of the engine would crack quite often, thus requiring a lot of down time for that scoop tramp and maintenance problems. By moving the compressor to the mainframe we have solved this problem by mounting it on a sturdy bracket which is welded on to the mainframe and bolting to the compressor on this bracket. The straps had to be modified in the new modification. The compressor was lifted also by about four inches in order that the oil in the compressor would drain easier into the engine. The simple modification has eliminated a lot of costly maintenance and down time which used to re-occur quite often during the operatio of the scoop tramp, probably once a month.

10) Continuous Polymer Feeding System

The Treatment Plant that you see here treats acid mine water from underground and daily seepage water by adding lime, adding polymer and allowing it to settle and clarifying in a thickener. This is a standard practice within the mining industries and represents a basic technology. The MTI that we are discussing here would represent a innovation on a polymer delivery system. The polymer delivery system is comprised of a waterflow into which concentrated liquid polymer is injected. The injected polymer is then allowed to mix in a flash dilution stage through some fittings. Small liquid polymer pumps are used to inject the concentrated polymer into half-inch tubing. After the injection and flash mixing of this particular system, the polymer solution is allowed to go into a carlon coil of approximately three hundred feet in which it gets gentle mixing and an aging process occurs to allow the full utilization of the polymer solution. As you can see here the coil of carlon has been encased in plastic shrouding. The entire Polymer delivery system here is very simplified compared to the original BIF poly-pack mixing system and allows a reduction in the cost of purchasing new equipment and also providing for an improved performance because of the simplicity of the design.

11) Noise Suppression Package on Scoop Tram

We are looking at an eight-yard Waggner Scoop tram, to which we have added a noise supressant package. The package cost approximately $4600, including labour to install. It consists of two side panels and a top panel around the engine compartment. It was intended that this package would reduce the noise level at the operator's compartment by approximately ten decibels. The installation to date has reduced the decibel level by 5 db, however, we have not yet included the installation of panels around the transmission, side of the transmission and the torque converter. Benefits to date have been enhanced by cooler operating temperature around the operator and also a reduction in the amount of dust which is blown up by the air blowing through the engine. As we look at the installation, you can possibly see the perforations in the base metal under which the accoustical material is attached. Looking at the side you can see the panel, side panel which is held down by clips which, when removed, allow the side panel to slide up through a channel. As we move in we see the accoustical material which is attached to the cover which opens up to allow access to the oil filler pipe. Looking into the dipstick compartment as we move back we will be able to again see the side view, left-hand side of the machine and the compartments as I noted.

12) Modification of Seating on Scoop Tram(Horne Mines)

The following is a modification done to the scoop tram. The modification consists of enlarging the operator's compartment for the operator to have more leg room and an easier access into his compartment. The original machine has quite tight quarters for the operator. The process involved extending the cabin or the operator's cabin out to the exterior of the scoop tram, about 3-4". The back seat of the operator seat was rebuilt using half-inch plate, which is bolted on to new brackets on each side of the driver's seat. These bolts were installed so that if the back coming out of the driver's compartment is bent, or for some reason, damaged, it can easily be removed and replaced by a new one.

13) Bulk Cyanide Handling and Mixing System (Geco Mill)

This is a current procedure for mixing sodium cyanide using a 2000 pound container of cyanide, which replaces a previous method using 9 drums containing 220 lb. sodium cyanide. That operation required approximately two hours of mixing. This method requires approximately 10-15 minutes from beginning to end, and was found to be much more safer and efficient operation. The sack is presently being lowered into a hopper containing a piercing arrow which allows the cyanide to flow through the hopper into a mixing vat collapsing the sides of the sack. The operator is now removing the sack above the hopper which he will cut with a knife and wash the interior of the sack removing any particles of cyanide which remain in the sack. The sack is then hoisted over to be placed back in the shipping crate. This crate and liner will be disposed of by burning.

14) Friction Washer for Screening Support (Brunswick Mine)

This is a friction washer for screen support. The reason it was developed was to replace rock bolts in the middle of the screen. Since we are using double threaded rock bolts which has a threaded end protruding from the back, these washers can be pushed on to this threaded end. These washers have been tested; they can hold up to 1800 pounds each. They can be placed on the bolts either using the drill or by hand, using a dolly at the end of a steel or any other type of pole. This is how the product looks when it is being used properly. The friction washer is essentially a steel plate which has some tabs on the bottom to secure it on the dolly and two tabs on the top of it. The tabs on the top are used to hold the wood washer securely in place. This reinforces the washer and also reduces the amount of rusting that may occur on the screen. The rock bolt dolly fits into the tab to hold it while it is being lifted on to the rock bolt. We have determined that we have annual savings of up to a million dollars by using this washer to replace rock bolting in the middle of the screen.

15) Screening of Ore to Avoid Bin Freezing

The screening of pit run ore to eliminate bin freezing and stock pile handling problems during winter months was a major concern to us. During the winter of 1982 we were only able to achieve one-third capacity due to bin freezing problems. During the reopening in 1984, a committee was formed and one of the results of their investigation concluded that the main problem in winter freezing problems was a result of the fine material in the ore. It was decided to try a screening process comprised of a feed hopper conveyor and vibrating screen arrangement. A Coleman screen was used for this purpose. The coarse material, anything over two inches, was trucked directly to the mill. The fine material was stock piled until the Spring. The results of the 1984 operations was that the mine operated throughout the winter on full capacity. Crusher coarse ore storage was at a hundred percent utilization and we had no problems whatsoever handling surface stock piles. At present we see the stripping of slag for the small open pit, the fine material is being used to fill a large underground opened stope and the coarse material is being trucked away as back fill. The reverse was the case at the pit operations where the coarse was the primary product being used to supplement the mill and the fine was being used as a future source of stock piling material. It should be remembered that any screen device can be used and you are not limited to ores but to any surface stock pile material which must be handled several times during the winter.

16) Mobile Waste Oil Tank (Lyons Lake Mine)

Here we have a mobile waste oil container used in small mobile shops underground for heavy equipment. It is used to get it to the machines so that you could dump, spill oil from engines, hydraulic systems whatever, so it's not all over the floor, and hanging around the spill trays and being left in 45 gallon drums. It can be moved to any machine location in the shop. Due to the fact that it is fitted with castors, moveable at the rear for steering and rigid at the front, it can also be used in the drift where the drifts are paved. It reduces manpower when handling 45 gallon drums, debris, messy oil. It eliminates all that. Once a week it can be emptied and transported to wherever you get rid of your waste oil. There you can see the spout for it, that's where you pour in your waste oil; it's fitted with a screen to pick up nuts and bolts, blown hoses whatever you have. You have a spout on the tail-end of it which is just a pipe cap which can be removed. An air pump can be put into it and pumped into whatever container you are using to dispose of it finally. It has been used in our shops at different locations and it seems to doing the job all right.

17) Earthwork Supports For Tailing Pipes (Brunswick Mill)

The tailing disposal area of this property consists of about 600 acres. Stored to date is approximately 47 million dry metric tons. What we are looking at now is a tailings trestle that takes the end spill and carries it out to the central area of the pond which is the slime portion of the tailings. Carpenters and labours construct wood end spills to get the pipe out, approximately 150 feet from the perimeter dike. What we are starting to look now is the new method which involved changing from wood end spill to using the dry tailings using hydraulic backhoe to put the bank in place. The new method has reduced the cost of building end spills each year as the tailings levels rose. The new method using dry tailings annual cost about $1500 as compared to the old methods using the wood trestles with annual costs of something like $13,000. We have found that the new method to be simpler and easier to work with.

18) Computerization of Clerical Duties (Horne Mines)

A review of the work practices of our engineering and technical staff indicated that an excessive amount of time is being spent on essentially clerical functions. These included a manual compilation of data for bonus calculations, data statistical and production reports, unit cost reports, performance reports and others. The amount of time spent varied from a minimum of one hour per day to an unacceptable four-man weeks at month end. The potential for computerizing these requirements seemed to be ideal resulting in more time available for technical staff to pursue primary functions; whether it be surveying ventilation monitoring, planning or troubleshooting. The application we are describing here is where we have combined payroll, bonus and productivity statistics into one operation. The data base program is now known under the tradename of Data Ease. It was developed by the same company that produces the Lotus 1-2-3 software package. It essentially combines the Time Clerk and the Bonus Technician's function into ~~one.~~ Daily reports are input into a recess screen and all pertinent payroll, accounting and bonus data is entered for each employee. The program is entirely menu driven with several separate menus used for data input, report generations, system management functions and data management functions. Reports that are generated but are not eliminated to daily hours by employee, daily hours by contract, daily hours by work type, or work place, monthly hours by contract by employee, several payroll reports. The savings from this program resulted in over one hundred and eighty hours per month. The student that did this manually prior to the program's implementation was not replaced when he returned to school. It could be seen as a concrete example of the actual savings that can be incurred by our computer use in the mining industry.

19) Cappel Remover For Skip

What we are looking at here is the shaft with the skip right at the collar and the hoist cappel which attached to the rope and to the skip. The problem we have here is when you disconnect the cappel from the skip it whips around due to the tension on the rope and could possibly injure someone. Here we have made, what we call a cappel remover and it is used to hold the cappel from whipping out of the shaft.

Now we are installing the capel holder and it fits over top of the cappel on to the shaft guides and is bolted together. When the cappel is released it jumps up and spins inside the tube housing of the holder. This is the holder apart on the floor - it's made simply of an 8" piece of pipe cut in half with a couple of 3" channel welded onto the pipe which is bolted together.

20) Radio Headsets For Crane Operations (Brunswick Mill)

This is a mining concentrator. What we are showing you is a mechanic using battery operated headphones in communication with the crane operator. We use these headphones to communicate back and forth between the inside of the mill and up to the crane operator which is a distance of 35-40 feet. Before we were using wire to connect the two which was very very difficult to use inside the mill because of obstructions and people climbing and walking on top of cable. We also use them in several other applications, but this is the main function we use them for today, that is changing the lining of the rod and ball mills. For communcation inside we find they work very well and it has saved us considerable amount of time. The headphones themselves are attached to an ordinary hard hat, they are very good because you don't hear the outside noise because they are a sort of an ear muff at the same time. They are light, they are not hard to use, there is no connecting cable and they are battery powered. There is a silencer that quiets the background noise so that you can talk even in a very noisy area with very good response at both ends. The cost of these are approximately $2500 per set.

21) Battery Charger for Remote Scoop Tram Transmitters (Horne Mine)

This is a new kind of kind of battery charger. We had one battery charger before and we build this one so we could have more batteries available, one battery was not sufficient for the work we had to do. I am putting the battery on charge now from the scoop transmitter, checking the voltage on the battery before I put them on and then I set the timer on it takes about 16 hours to charge those 10 batteries, 5 each side of the charger. We put 5 batteries on each side because this is the number we need for every transmitter that goes with the scoop. Before they (the mine department) used to charge 1 battery and change 1 battery at a time, it didn't have enough power to last all day, it took 5 batteries so we made a charger for 5 batteries. O.K. now, this battery charger is set so that if a battery is a little lower than the other one it takes the same charge as the other one and they are all the same after 16 hours. They are all charged the same by this automatic charger. We made this tester in our own shop here instead of buying an expensive charger. We made it from what we had in the shop here and bought a few more parts. It works very well.

22) Rock Breaker Setup Modifications (Mattabi Mine)

What we are going to be seeing here is the rock breaker and grizzly system as installed. This mine's rock compressive strength is around 60,000 psi so we have quite a problem with that. We decided to go with hydraulic hammer on the rock breaker and 6" x 12" grizzly beams. Because of the high compressive strength of the rock, the rock breaker base gave vibration problems and the cab of the rock breaker. We just saw a channel beam that was welded on to try and hold the rock breaker down. The top of the cab you could see was lifting off from the vibration. On our new set up on the 1550 level we see the ore pass coming down. We've tried to incorporate some new changes to improve this system. One of these is moving the cab off the rock breaker base on to a stand of its own. This gives the operator a better view of the work being done and free from flying material coming from the ore pass above. This also has the advantage of opening up areas for the hydraulic hoses and connections, so the mill wrights have an easier job of repairs. Continued with the same grizzly design. You can see the cab of the rock breaker. We are still in the construction process here. Around the edge of the grizzly we have 6" x 24" steel beam backed by a foot and half of concrete all reinforced. This is because the curb bumper blocks were being destroyed at our other installation, the hammer was being rested on it - you can see the bumper block in that shot. The rock breaker bases were beefed up and more steel work added. Better bolting systems to hold the cabs and the base stand in place. This shot shows the ore pass coming down from above in direct line with one rock breaker and the other rock breaker was at 90 degrees to this line. The grizzly set up with the 6" x 12" beams has stood up extremely well and completely maintenance free the only wear shown was rounding of the top corners of the retainer wall.

23) BBC - 120 Drill Modifications (Matagami Mine)

This modification was made to change the threaded retainer and locking spring on the front end of a BBC120 machine. It was found that the threaded retainer would work loose and, due to vibration, the threaded cap and retainer would be damaged after a period of time. This retainer was replaced with a home-made retainer which was bolted to the casing. This has saved approximately $3,000 in material costs per machine per year. In the photograph, is the original front end of a BB120, the original retainer and spring locking device. The new modification involved the welding of two ears to the casing of the BBC120 with two holes of approximately three-quarters of an inch in diameter. This is a picture of the new retainer ring cap in place bolted to the machine. This new retainer cap is a piece of 1" metal milled to fit the front end of the casing and bolted to the machine. As one can see this is a very simple device to install on the front end of a machine and this picture shows the retainer cap in place in the machine and the operator himself where he is making the change. Adjustment is just a matter of using a Westcott wrench because the heads of the bolts are locked in place.

24) Smoke Detection on Ventilation for Mine (Horne Mines)

This is a compressor room. The big pipe you see outside is set-up with the intake air on the ground so the warm air from the compressor goes into that pipe and down underground to warm up underground. But if we ever have a fire in the compressor room an automatic smoke detector will stop the compressor, stop the fan and open the trap so that the smoke goes outside. What you see in the red box outside is the smoke detector. And this is the inside of the compressor room and up on the ceiling you will see the smoke detector that detects smoke in the compressor room, or a fire which will, like I said before, open the trap outside and shut the compressor off. This is the box that was inside the red box and there's a key on it to turn it on. The smoke goes in by the back end and it automatically stops the compressor and that key is used then to prevent the compressor from stopping while we are making repairs in there.

25) Copper Sulfate Mixing System (Mattabi Mill)

We are viewing the old copper sulphate system in the mill. We added copper sulphate into a hopper by forty 25 kilogram bags per day, done by an operator, which was rather labour intensive. We had problems with lumps in this hopper which slowed down flow into a mixing tank below. Basically the copper sulphate was fed continuously into the mixing tank by a conveyoer belt, you can see the hopper there. Now we had two tanks one is a mixing tank and the other was a holding tank. We had problems with the consistent strength of the copper sulphate due to the stoppage in flow. We had the old system of putting in the bags and as you can see now we have the one ton bags for adding copper sulphate into the new hopper which you now see. Copper sulphate is fed via a screw conveyor on a batch system, an one ton bag at a time into a mixing tank down below and water is added simultaneously with that copper sulphate. There's an electrical panel where we have the starters for the mixing system motors and pumps and also a basic control unit to determine the right amount of water and time needed for mixing. It's a much simpler system as the operator only has to handle the copper sulphate twice a day. There's a close up of the screw conveyor, it's fairly short so you don't have any problems with the blockage, it's easy to clean off if that does happen. The next view is of the mixing tank down below which is constructed of fibre glass. It holds enough to feed the zinc circuit for about 10 hours. From this tank it's pumped via a small plastic pump to a holding head tank which is above the flow-rater. This flow-rater was designed by Noranda Research and installed by Mattabi personnel. This is the flow-rater installation which replaces a very little Milton diaphram pump. We have problems keeping that pump calibrated for more than a week at a time. Total savings over the course of the year was around $30,000 per year for copper sulphate. The operators find it is much easier to use as they can just view the flow in the column. S.G. is monitored by the computer and flow from this set up. S.G. can also be determined by the operator from the small hydrometer sitting in the still well at the bottom of the flow-rater.

26) Production Blast Hole Caseing Collars (Matagami Mine)

This modification was made to install an 8" diameter casing in the collar of all our six and one-half inch holes drilled by a down-the-hole drilling jumbo for production. Due to multiple blasting in the holes the collars would be damaged and this would result in blocked holes and excessive cleaning of the floor after each production blast. Production flash holes will be used 4-6 times and the slot holes will be used 20-22 times. As one can see the collar of our holes will deteriorate rapidly due to the number of blasts. This picture shows the steel in the hole and the casing. As one can see the casing is 1" diameter inside, and this casing is installed with a reaming bit from 6-10" which is drilled 5′ down and a 5′ casing is installed with the cuttings plus a small amount of cement is used. This is a picture of a casing. This is the photograph of the 6-10" reamer bit. The holes are drilled and then the reamer bit is used to ream the hole the first five feet of the collar. This is a picture of the casing plus the wooden plug which is installed in the holes so as no material can fall in the holes to cause the hole to plug later on. These plugs are made at the carpentry shop. This is a photograph of a hole where they installed a plug after it has been drilled. The safety aspect of this modification results in no floor upheaval which results in a very level floor because the casing protects the collar of all the holes.

27) Dust Collector Over Slot Feeder (Mattabi Mill)

We are currently looking at the slot feeders underneath the fine ore bins and these slot feeders are basically feeding conveyor belts which drop down onto a collection conveyor belt and at these drop points dust is created when the ore is very dry. Initially we had no dust collection system in here. Just looking at one of the drop points, you can see the slot feeder. We had a lot of problems in the mechanics area which is adjacent to this area with dust obviously creating a very bad working environment. Now every drop point is enclosed or shouded - you can see the cover on the inspection panel there and you can see through the plexiglass panel, to make sure that there is no build up of material. Currently the air is being pulled through a header pipe into a Ducon dust collector where the particles are impacted on a water spray. The machinery is obviously of the propeller type. Once the particles have been impacted ~~they~~ form a slurry with the water which drops down to the bottom of the chamber and from there it goes into the grinding circuit and mixes with the rest of the material which comes out of the grinding mills. A very nominal amount of water is necessary to run this operation so we do not increase the amount of water used in the mill significantly.

28) Sulfur Dioxide Conditioner (Matagami Mill)

This is the solution to the problem we had with the sulfur dioxide (SO2) conditioner. Previously we had SO2 fumes exhausting from top of the container. We had a problem with the mixing of the pulp in the conditioner. The agitator or spindle would frequently sand up causing an overflow. Another hazzard was that it would flow on to the floor causing a dangerous work situation. The modified system for the SO2 conditioner is a self-contained unit. As you can see it is fed from the bottom of the unit. Pulp pumped in from the bottom causing a mixing action. The column is some 11' in height. The SO2 toxic gas is injected into the column. As you can see from the top of the column there is an exhaust pipe which will exhaust to atmosphere. The overflow pipe is located on the top of the column. This column eliminates a lot of sanding up. It eliminates the toxic gas escaping into the plant.

29) Drill Hole Dewatering (Gaspe Mine)

We have recently been gradually modifying our mining methods; introducing long hole mining methods. The purpose of adopting this method was to cut down on our mining costs and improve our efficiency. In most of the stopes, the residual water left in the hole is coming from the drilling itself. There is no water seepage in the hole itself. What we did was dewater our holes and change from Tovex explosives to Anfo explosive. In doing so we have estimated that we can save up to half a million a year.

The cost of the pump itself is approximately $15,000. The pump is introduced into the hole with an electrical cable to drive it. The pump is supplied by a generator driven by a diesel engine.

Once each hole is dry then we can start with the loading of the explosive itself. The bottom of each hole is loaded with Tovex in order to make sure everything is dry. We then load with Anfo. This is the major cost saving.

30) Slurry Screen for Pressure Filter Feed (Matagami Mill)

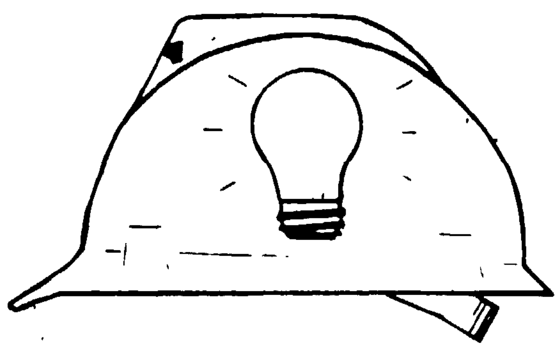
This is a modification we have done to our Larex pressure filter system. We have installed on the feed pipe a chamber, 2 feet in height and 8" in diameter. It filters the feed and removes trappings that would have gone directly into the feed column. The trapped debris can be removed from the vitallic coupling, from the top of the chamber and checked periodically for wear and conditioning. As you can see the top of the unit has a vitaulic type coupling with an extended handle on it for easy opening of the unit to remove foreign particles, or the basket for cleaning purposes. The basket or filter, is a screen type unit to remove those particles. It is very easily reinstalled quite quick with the vitalic coupling and the extended arm on the side. This checking process takes probably two or three minutes of your time. In general, this unit eliminates a lot of production down time and eliminates a lot of costly maintenance.

APPENDIX 2

DESCRIPTION OF MTIs IN WRITING

This appendix contains a copy of the booklet of written MTIs sent to each participating operating unit. It cites 43 MTIs of which 33 are PMTIs and 10 QMTIs. The booklet also contained the questionnaire used to collect NOU responses of actual or potential use. The appendix begins with a listing of the written MTIs, their OOUs and type. The MTIs are listed in the order that they are presented in the booklet.

MINOR TECHNICAL IMPROVEMENTS FROM NORANDA OPERATIONS



MCI FROM MILL / CONCENTRATOR OPERATIONS

DUST SUPPRESSION SYSTEM ON LEAD DRYERS 1

DENSITY CONTROL OF SETTLING THICKENERS 2

LINATEX PUMP IMPELLER MODIFICATIONS 3

POSITIVE LOCKING PLUGS 4

LOW FRICTION CASSETTES ON CONVEYOR BELT SYSTEM 5

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TAILING LINE SUPPORTS MADE FROM PALLETS 13

IMPROVEMENTS IN ORE BIN FLOW BY USE OF CALCIUM SOLUTION. 14

LIME DEGRITTING 15

DUST SUPPRESSION SYSTEM ON LEAD DRYERS

1

This MTI involves the instrumentating of dryer head conveyors with load sensors, minimum speed detectors and plug chute probes. The function of the unit is set up in a small control box which senses a lower rate of feed , plugged chute or coveyor slippage. Upon finding this change the interlock shuts down the dryer furnace. This avoids over heating and burning of concentrates thus lowering dust levels in the concentrator building. Estimate cost of equipment is $7,700.00 .

CONTACT : D. M. Wood
Concentrator Production Superintendent
Mill Department
Brunswick Mines
(506)-546-6671

DENSITY CONTROL OF SETTLING THICKENERS

2

This MTI involved instrumentating a 3 x 3 pump with a density meter, two controllable valves and programmer. The objective of the MTI was to settle a low density slurry, remove slurry at a preset slurry density, and return slurry to the thickner which had not thickened. This was accomplished by connections under the flow line of the thickener to the intake of a pump. The discharge line of the pump was connected to two valves. Between pump and valve a density meter was installed. When the density was below the desired value, one valve opened to return slurry to the thickener. When the density reached the desired value, the valve on the cone line closed and the discharge valve to the storage tank opened. The advantage of this system was that it avoided the resettling of high density slurrys. Cost of system was estimated at $ 12,500.00.

CONTACT : D. M. Wood
Concentrator Production Superintendent
Mill Department
Brunswick Mines
(506)-546-6671

LINATEX PUMP IMPELLER MODIFICATIONS

3

Prior to these modifications, a Linotex stock impeller tended to last 500 hours of operations on a tailings pump. Then the impeller, made from layers, of rubber would delaminate or the metal core would shake appart due to poor balancing. The mill modified the design so that the metal core was welded rather than bolted together. Then it was vulcanized. The core machining and vulcanized was contracted to outside suppliers The impeller was balanced before and after vulcanization. The tailings pumps now experience 12,000 hours of operation before replacement or major servicing.

CONTACT: Rick Watling
Underground Mechanical Planner
Mill Department
Brunswick Mines
(506) 546-6671 Ext 6697

POSITIVE LOCKING PLUGS

4

Plugs in the mill use to be placed manually into boxes used to split loads from pumps.The plugs would work loose leaking into the box or down the wrong pipe. A solution was found by mounting the plugs to the junction box. A spring loaded hand clamp was used to raise and lower the plug and also lock the plug into position. With this MTI the problem of mislaided plugs was also avoided. Approximate cost of the each box made by a supplier is $400.00 to $500.00.

CONTACT : John Gionet
Senior Operating Foreman for Crusher
Mill Department
Brunswick Mines
(506) 546-6671 Ext. 6613

LOW FRICTION CASSETTES ON CONVEYOR BELT SYSTEM

5

The conveyor belt systems use to be supported solely by Jeffrey impact idlers (rollers). Large chunks of ore, aproximately 3' in diameter, often fell from chutes breaking the impact idlers resulting in daily replacement. The mill department started installing low friction sliders at these stress points. The belt sliders are teflon coated guides rather than rollers which offer better support for the belt. Sliders cost $ 7 - 8000.00 per unit and replace 10 idlers each costing aproximately $ 300.00.

CONTACT : John Gionet
Senior Operating Foreman for Crusher
Mill Department
Brunswick Mines
(506) 546-6671 Ext. 6613

BIPOD FOR MILL LINER INSTALLATION

6

The removal and installation of steel ball mill and rod liners has traditionally been a labour intensive job which requires excessive handling. End liners come in two pattern designs. One weighs 320 lb, and the other 450 lbs. The liners have bolt holes for fastening them to the mill's outer shell. In the former method of installation, two scaling bars were slipped through the liner's holes and then 4 men manoeuvered the liner into position. The risk of injury from man-handling and lifting these liners in confined quarters led to the development of a simple and inexpensive bipod. The bipod is contructed of steel pipe and has a chain block suspended from the top. Both legs of the bipod are firmly anchored in the slug or rod bed while the top is braced against the end wall. A liner is hoisted on the chain block, then pushed into final position using guide bars.

CONTACT : Gerry Schweer
Mill Maintenance Foreman
Mill Department
Geco
(807) 826-3211 Ext. 281 or 235

IMPROVEMENTS IN ORE BIN FLOW BY USE OF CALCIUM SOLUTION. 14

A major problem was encountered during winter with slag ore packing together and not flowing out of the bins. The old sloution was to blast or heat the ore from the bottom of the bin. This was time consuming. The solution found was to spray calcium solution into the bin from the top of the bin. Given two days to work, the ore was loosened sufficiently to flow freely. The calcium can be sprayed on an ongoing basis to prevent bin freezing all together.

CONTACT : C. Desrouches
Chief Mettalurgist
Concentrator Department
Horne Division
(819) 762-7764

LIME DEGRITTING 15

A device was designed to remove the grit (sand) from milk of lime slurry after shaking. The principle involved is a combination of gravity settling and cycloning. The grit settles to the bottom of a cyclone shaped device and is discarded on a predetermined frequency.

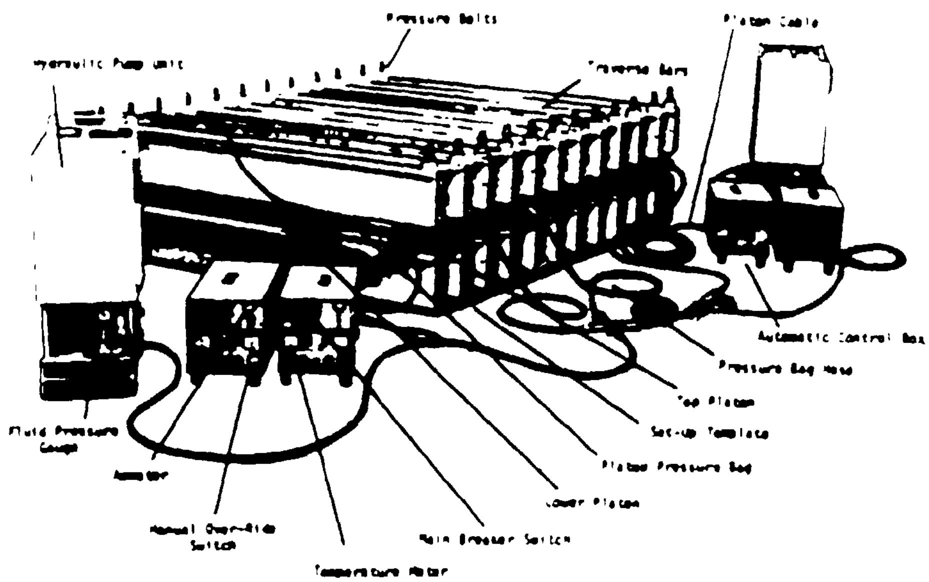
CONTACT : S. Beaullieu
Asst. Mill Superintendent
Concentrator Department
Mattagami Division
(819) 739-2511

HOT SPLICE VULCANIZING FOR CONVEYOR SYSTEMS

The old method of servicing conveyor belts involved splicing a section of conveyor belt together by glueing the two ends. A setting time of at least 6 hours up to 24 hours (as suggested by manufacture) was required. Frequently a drying time of 24 hours was not possible due to the demands of production. The mill department bought a hot splice vulacnizer from Shaw-Almex of Parry Sound. The device cooks the glued ends of the splice at 300 degrees Faranheit under pressure. The drying time is not required with this method and the splice is more durable. The equipment will handle up to conveyor belt widths of 72". The equipment ranges in price from $ 15 - 50,000.00 depending on the size of set up.

CONTACT : Mike Morton
Rubber Shop
Mill Department
Brunswick Mines
(506) 546-6671 Ext. 6635

FUNCTIONAL DIAGRAM



FLOC SETTLING RATE MONITOR (FSRM)

8

Most treatment plants operate without a means of determining correct polymer dosages. In many cases, the loss of polymer addition is not noticed until the clarifier or plate pack is "upset". The FSRM consists of a sampling ball valve, sample line, 3 inch diameter acrylic tube about 4 feet long and a high intensity infrared receiver-transmitter set with transistor logic. A PLC opens the sampling valve for a minute allowing a flow of treatment plant clarifier influent to enter the bottomof the acrylic tube and overflow out the top. Then the ball valve is closed and a settling timer is activated by the PLC. The settling timer is controlled by the "infrared set" which is mounted accross the acrylic tube at about mid height. As the floc in the tube settles, the infrared beam is obscured until the floc interface drops below the "infrared set". When this occurs the interruptable settling timer within the PLC is stopped which provides a relative measure of the floc settling rate to operators. This cycle is repeated every 500 seconds. Equipment costs are estimated at $700.00.

CONTACT : Walter Sencza
Environmental and Process Control Engineer
Mill Department
Geco
(807) 826-3211 Ext. 274

GROOVING OF POLYETHYLENE PIPE WITH ROUTER FOR BETTER COUPLING

9

Grooving is required to connect plastic piping throughout the mill using victaulic couplings. Short sections of polyethylene pipe were previously grooved at the machine shop on a lathe. This meant uneven groove depth and numerous delays. It was then decided to attempt grooving the pipe in the field using a portable router. The 1 horsepower uses a normal bit and guide. The equipment costs $150.00 .

CONTACT : C. Ferron
Chief Metallurgist
Mill Department
Geco
(807) 826-3211

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CONTACT : C. Perron
Chief Metallurgist
Mill Department
Geco
(807) 826-3211

LIME MIXING SYSTEM

10

Originally lime was mixed in a funnel with water and fed by gravity or pumped to an addition point. Funnels frequently plugged as did gravity lines. This method was changed to a two tank system. The first tank had a samll mixer to insure better contact between water and lime. The solution overflows to the second tank which has a funnel-shaped bottom attached to an eductor. The water eductor serves as the mixing point between the lime slurry and the fresh water which will transport the slurry to the addition point. Equipment costs are approximately $5 - 600.00.

CONTACT : Walter Sencza
Environmental and Process Control Engineer
Mill Department
Geco
(807) 826-3211 Ext. 274

AIR NOZZLES FOR AERATORS

11

Previously mill aerator tanks were aerated by drop pipes coming down from the top of the aerator. These were heavy to handle, hard to clean, and difficult to maintain. An idea was borrowed from Mattabi, which used air nozzles in the bottom of the aerators. The air nozzles have flap doors made of soft material (Linatex) which prevent the air nozzles from plugging if air flow ceases. Cost per application is aproximately $1000.00.

CONTACT : G. Schweer
MTCE Foreman
Mill Department
Geco
(807) 826-3211

RUBBER PLUGS TO SEAL BOLT HOLES INSIDE BALL MILL LINER **12**

A problem was experienced with the primary mill when lifters were being changed at the discharge end. Fine slag would get behind these bars and into the bolt holes. This fine slag would become as hard as cement, which would make it extremely difficult to remove the worn bars when replacement was necessary. The solution found was to install a soft rubber ring around the bolts and under the lifter bars. This MTI saves $ $1200.00 a year and has also reduced mill downtime and accident risks.

CONTACT : C. Desrouches
Chief Mettalurgist
Concentrator Department
Horne Division
(819) 762-7764

TAILING LINE SUPPORTS MADE FROM PALLETS **13**

Rather than building a support trestle for tailings pipe from new wood, old or surplus pallets were used to support the tailings lines. In the past, the pallets would have been destroyed. This MTI reduces the cost of the materials used and speeds up installation time.

CONTACT : C. Desrouches
Chief Mettalurgist
Concentrator Department
Horne Division
(819) 762-7764

IMPROVEMENTS IN ORE BIN FLOW BY USE OF CALCIUM SOLUTION. 14

A major problem was encountered during winter with slag ore packing together and not flowing out of the bins. The old sloution was to blast or heat the ore from the bottom of the bin. This was time consuming. The solution found was to spray calcium solution into the bin from the top of the bin. Given two days to work, the ore was loosened sufficiently to flow freely. The calcium can be sprayed on an ongoing basis to prevent bin freezing all together.

CONTACT : C. Desrouches
Chief Mettalurgist
Concentrator Department
Horne Division
(819) 762-7764

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A device was designed to remove the grit (sand) from milk of lime slurry after shaking. The principle involved is a combination of gravity settling and cycloning. The grit settles to the bottom of a cyclone shaped device and is discarded on a predetermined frequency.

CONTACT : S. Beaullieu
Asst. Mill Superintendent
Concentrator Department
Mattagami Division
(819) 739-2511

MTI FROM MINE AND PLANT OPERATIONS

UNDERGROUND EMERGENCY VEHICLE 1

CABLEBOLT FEEDING MACHINE 2

CABLEBOLT CUTTING DEVICE (META - CAB) 3

ROCK BOLT DOLLIE 4

REPLACEMENT OF MECHANICAL WITH HYDROSTATIC TRANSMISSIONS 5

PARTICULATE FILTER FOR DIESEL EMISSIONS 6

REPLACEMENT OF SCREW FEED WITH CHAIN FEED ON DRILL JUMBO 7

SAFETY LIMIT SWITCH ON TRUCK BOX CONTROLS 8

PRESSURIZED SYSTEM FOR CONE OPERATION 9

ELECTRONIC FAN REVERSING FOR VENTILATION AND COOLING 10

UNDERGROUND FUELING STATION 11

DEWATERING BOREHOLES IN MINE 12

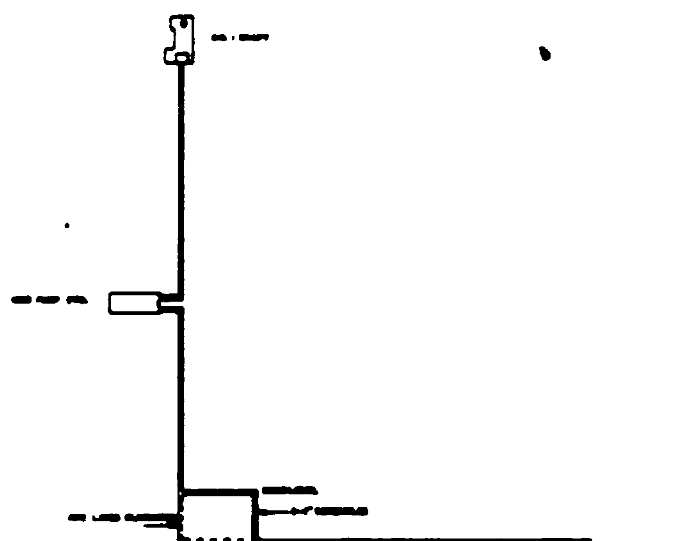
MAGIC HAMMER 13

12

DEWATERING BOREHOLES IN MINE

At Geco's #1 shaft the mine water dewatering pump station is located on the 2450 foot level. The water is pumped across the level to the shaft, and up to the 1250 foot level. The environment at the bottom of the shaft where the spill pocket and tailropes are located is congested and wet. These conditions make it extremely difficult to repair and maintain the pipes on a regular basis. A solution was found by drilling two six inch boreholes, vertically from the 2250 foot level to the 2450 foot level. The water would then be pumped from the 2450 foot level through these two, hundred foot boreholes and then across to the shaft at the 2250 foot level. As a result the congested part of the shaft was avoided. Due to the unique nature of the solution, a special high pressure casing was developed to adapt the dewatering pipes to the boreholes. Special care was taken to ensure that the holes were drilled in competant ground. The initial cost of the MTI was $37,000.00 . Payback was estimated at less than 2 years due to reduced repairs.

CONTACT : Kyaw Win
Engineer
Mine Engineering
Geco
(807) 826-3211 Ext. 209



UNDERGROUND EMERGENCY VEHICLE

1

A underground vehicle was designed for use in fire fighting and rescue work. The vehicle was designed to fit into the shaft. A number of features were fitted onto a MCJ7 jeep supplied by Miltor Drilling Equipment in Sudbury. Suspension was reinforced. The 120 inch long vehicle can carry 6 men plus 4 stretchers with casualties. It carries a 350 lb dry chemical fire estinquisher with 80' of hose as well as other rescue equipment. Total cost of jeep plus modifications was $ 39,000.00.

CONTACT : Don Gagnon
Project Technician
Mine Department
Brunswick Mining
(506) 546-6671

CABLEBOLT FEEDING MACHINE

2

This air powered device for inserting cablebolts into drilling holes reduces the labour hours spent feeding cablebolts into the stope back. The resulting manpower savings is one man per crew. Eliminates potential back injuries. The machine was found to feed 3 times as many cablebolts as the old manual method. The device itself weighs 40-45 lbs. and can be carried by one man. Mounts on the back of a truck or piece of mobile equipment. A roller mechanism feeds forwards and backwards by a half ton air powered chain hoist using a roller chain. Can be bought for $6000.00 or built for about $3500.00.

CONTACT : Don Gagnon
Project Technician
Mine Department
Brunswick Mining
(506) 546-6671

CABLEBOLT CUTTING DEVICE - DETA - CAB

3

This explosive device is used to shear off installed cable bolts. Can be used on rock bolts up to 3/4" in diameter. It eliminates the use of oxy-acetyelene torches and the associated fire and personal safety problems. Requires less set up time than old method. Electrically detonated, shaped charges shear off bolts individually or in clusters. Dupont manufactures the device under the trade name Deta-Cab for a retail price of $ 4.50 a piece.

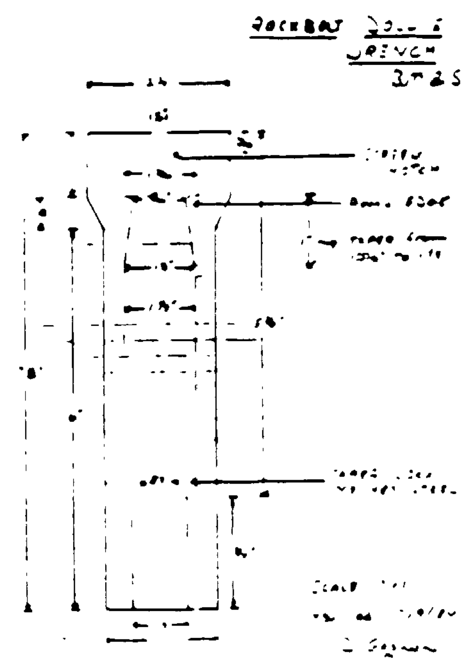
CONTACT : Don Gagnon
Project Technician
Mine Department
Brunswick Mining
(506) 546-6671

ROCK BOLT DOLLIE

4

This tool, commonly used to torque rock bolts into a drill holes, was redesigned especially for double threaded rock bolts. Due to various design features, the dollie reduces the binding of the wrench on the rock bolt. A taper-lock feature allows the wrench to fit securely onto the drill steel. It is lighter in weight compared to other types of dollie. It also has a comparitively lower cost of $15.00 per unit.

CONTACT : Don Gagnon
Project Technician
Mine Department
Brunswick Mining
(506) 546-6671



REPLACEMENT OF MECHANICAL WITH HYDROSTATIC TRANSMISSIONS 5

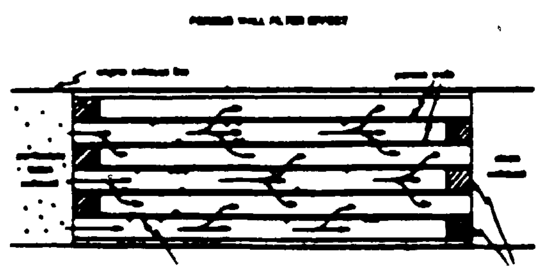
This change was made to Eaton Carrier equipment. Operating hours for this equipment were being reduced by the clutch wearing out. The axel within the transmission was breaking frequently. The clutch, transfer casing, and drive train were replaced with a hydrostatic pump and two hydraulic motors, one for each differential. The conversion was estimated at $28,000.00 per piece of equipment.

CONTACT : John Boyce
Mobile Equipment Maintenance Supervisor - Underground
Plant Department
Brunswick Mining
(506) 546-6260

PARTICULATE FILTER FOR DIESEL EMISSIONS 6

This device is to control smoke and soot emitted from equipment. A Corning ceramic product collects soot which drops out of the filtering element or is burnt completely. The filter requires constant high operating temperatures to function trouble free. Compared to regular air filtering devices, it does not choke up or smoke. This device is being tested at Brunswick in conjunction with Noranda Research and CANMET. The anticipated price of filter is about $3500.00 .

CONTACT : Ken Wheeland
Head of Environmental Technology
Noranda Research
240 Hymus Blvd.
Pointe Claire, Quebec.



REPLACEMENT OF SCREW FEED WITH CHAIN FEED ON DRILL JUMBO 7

The screw feed was expensive to maintain and replace. Replaced Atlas Copco Screw feed with Tamroc chain feed. Experienced a 60% reduction in maintenance costs for drill jumbos using the chain feed

CONTACT : Bob Baker
Industrial Engineering Supervisor
Plant Department
Brunswick Mining
(506) 546-6671

SAFETY LIMIT SWITCH ON TRUCK BOX CONTROLS 8

A problem was encountered with drivers failing to lower the truck box after dumping, resulting in damage to the truck and injury to the driver. A limit switch was installed that locks the transmission until the truck box is lowered to rest on the truck frame. The modification costs about $1200.00 per truck.

CONTACT : Jean Desrosiers
Superintendent of Mines and Mobile Service
Mines and Mobile Service
Mines Gaspe
(418) 734-2541 Ext. 130

PRESSURIZED SYSTEM FOR CONE OPERATION 9

The operator working area at the cone crusher was exposed to rock dust, high noise and vibration. A cabin was installed where from the operator could control the cone. The cabin is pressurized by a fan which draws directly from a mine air pipe.

CONTACT : Fulton Briand
Biologist - Hygienics
Environmental Services
Mines Gaspe
(418) 784-2541 Ext. 256

ELECTRONIC FAN REVERSING FOR VENTILLATION AND COOLING **10**

When the ventillation fan was shut off the draft from underground caused the fan to rotate backwards. In order to start the fan, the employee used a 2"x 4" board and pried under the shaft in an attempt to stop the fan before activating it again. The fuses burnt out because of the backward turning of the fan. Employees have been injured due to this problem. Three motros have been burnt out starting the fan. A "stearn electronic brake" was installed to stop the motor prior to starting. The brake works by magnetic force imparted from a direct current power source. The braking equipment costs about $3000.00.

CONTACT : Jean-Louis Frenette
Electrical Engineer
Engineering
Mines Gaspe
(418) 784-2541 Ext. 399

UNDERGROUND FUELING STATION **11**

Prior to this MTI, a truck equiped with two, 200 gallon tanks transported the fuel for equipment to two fuel tanks underground. Because of the small size of the fuel tanks on the truck, many trips were made down the ramp consuming manpower and contaminating the underground air. The new fueling station allows the fuel dealer to go underground with his own 2000 gallon truck equiped with a fume dilluter. Cost of fume dilluter modification was $1000.00 for a labour saving of one man.

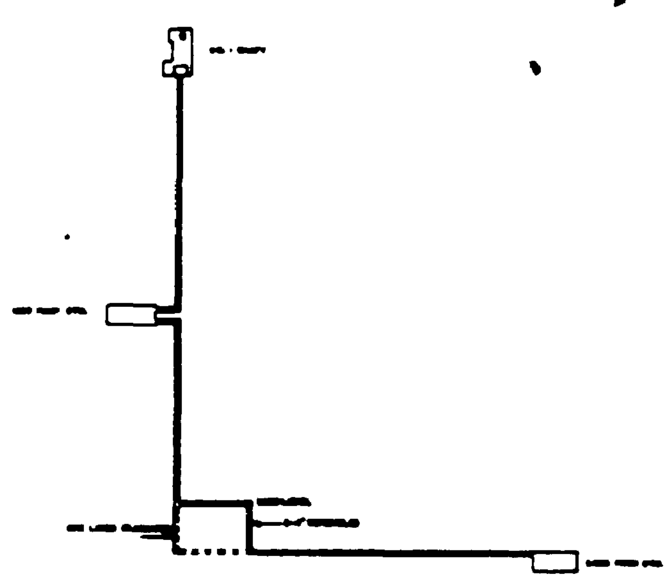
CONTACT : Jean Desrosiers
Superintendent of Mines and Mobile Service
Mines and Mobile Service
Mines Gaspe
(418) 734-2541 Ext. 130

12

DEWATERING BOREHOLES IN MINE

At Geco's #1 shaft the mine water dewatering pump station is located on the 2450 foot level. The water is pumped across the level to the shaft, and up to the 1250 foot level. The environment at the bottom of the shaft where the spill pocket and tailropes are located is congested and wet. These conditions make it extremely difficult to repair and maintain the pipes on a regular basis. A solution was found by drilling two six inch boreholes, vertically from the 2250 foot level to the 2450 foot level. The water would then be pumped from the 2450 foot level through these two, hundred foot boreholes and then across to the shaft at the 2250 foot level. As a result the congested part of the shaft was avoided. Due to the unique nature of the solution, a special high pressure casing was developed to adapt the dewatering pipes to the boreholes. Special care was taken to ensure that the holes were drilled in competant ground. The initial cost of the MTI was $37,000.00 . Payback was estimated at less than 2 years due to reduced repairs.

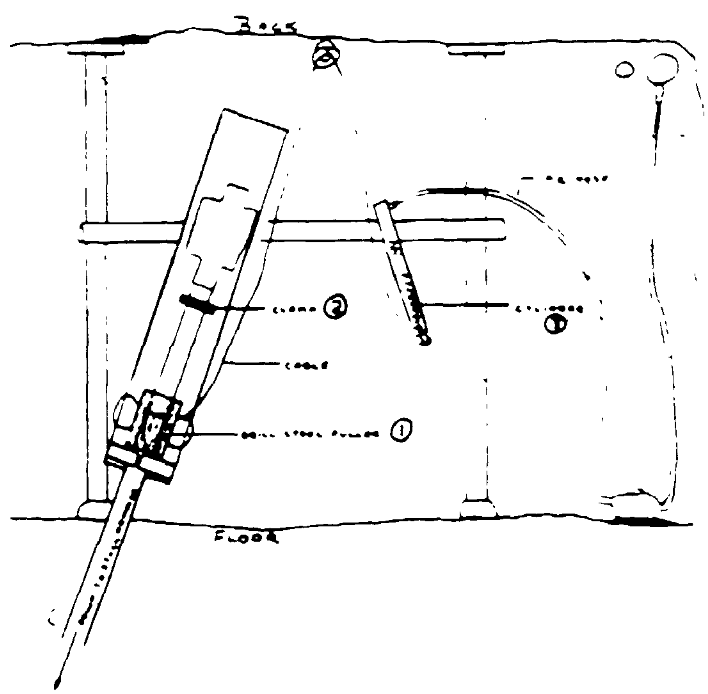
CONTACT : Kyaw Win
Engineer
Mine Engineering
Geco
(807) 826-3211 Ext. 209



MAGIC HAMMER **13**

A stuck I.T.H. hammer means the loss of not only the hammer but also the bit and a quantity of drill tube, unless it can be recovered. The magic hammer consists of 3 main parts. The drill steel puller (1) is slipped onto the potruding drill tube and rests on the centralizer. A clamp (2) is bolted onto the wrench flat of the drill tube. This clamp acts as a striking surface for the puller. A modified worn out Longtom cylinder (3) is mounted on the drilling bar so that a cable can be strung from the cylinder up through a pulley block on the back and down to the handle on the side of the puller. When the air is opened the cylinder extends and the puller is moved quickly up against the clamp, dislodging the hammer. The puller costs about $300.00 per unit to make. The puller has helped to recover 95% of stuck hammers.

CONTACT : Ken Byberg
Chief Mine Engineer
Mine Engineering
Geco
(807) 826-3211

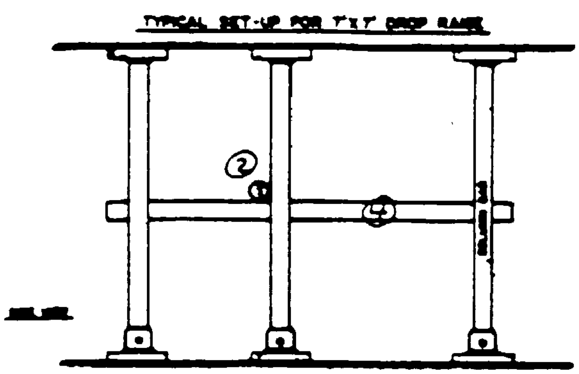


SQUARE DROP RAISE SET-UP

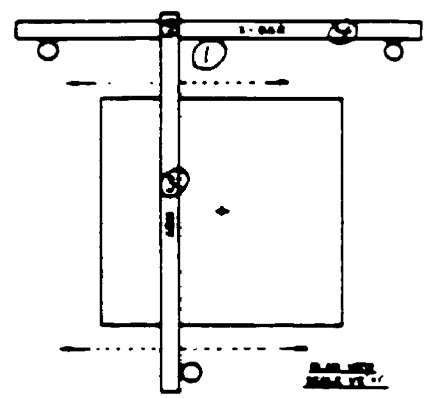
14

Problems with accuracy when drilling drop raises other than vertical prompted the design of a better set up. Used for 4 1/2 " I.T.H. drilling, this set up consists of 3 upright bars, an arm and a cross bar, forming a "T".(1) A univeral joint (2) connects the arm (3) to the cross bar (4) keeping them perpendicular to one another. By loss-ing the univeral joint and the bar jack at the other end of the arm, it is a fast and simple matter to locate the arm where desired along the crossbar.

CONTACT : Ken Byberg
Chief Mine Engineer
Mine Engineering
Geco
(807) 826-3211



SIDE VIEW



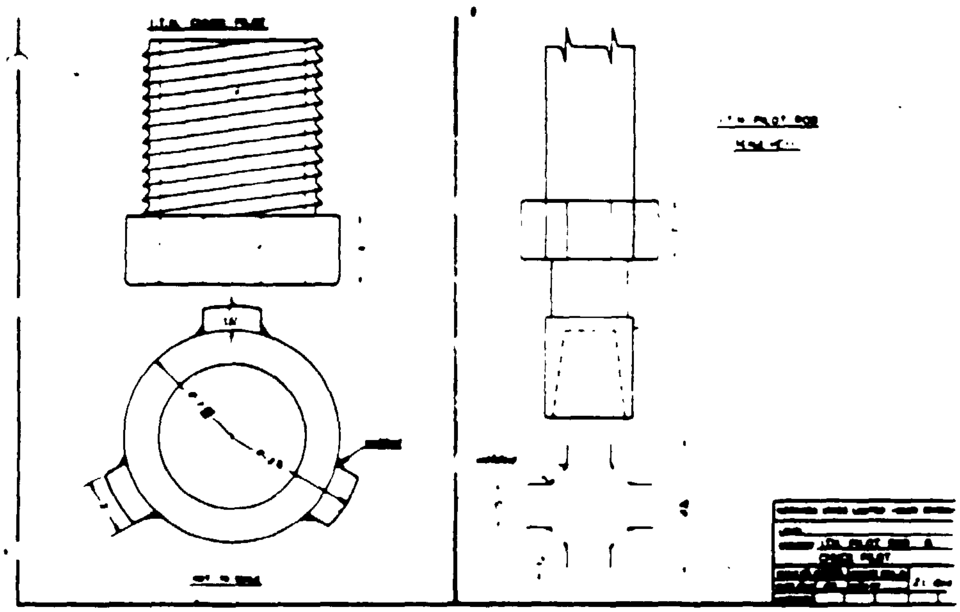
OVERHEAD VIEW

DROP RAISE-DRILLING WITH I.T.H. Drill

15

Control of deviation in drop raise drilling is critical, therefore a system was developed. A pilot chuck and pilot rod was fabricated to match the bit. A new bit and pilots are a set and are used until the bit guage gets down to about 4". At this point a new bit and pilots are used to continue drilling. In this fashion the pilot chuck and rod wear the same. To provide maximum accuracy the bit is sharpened every 40 feet or as required. The pilot guages are also checked to ensure continued compatibility with the bit. The first cut hole is drilled as above. An 8 foot reaming pipe is lowered into the hole with a handwinch. A second hole is drilled tight to the pipe to make a single large cut hole. This second hole is drilled with one of the small guage bits and no pilot chuck or pilot rod is used. As drilling progresses the pipe is lowered to remain at the same depth as the hole.

CONTACT : Ken Byberg
Chief Mine Engineer
Mine Engineering
Geco
(807) 826-3211



ANFO TOTE BAGS IN QUARRY 16

Previously, the Quarry blasts were loaded by manually pouring approximately four hundred - 55 lb bags of Anfo into 4" blast holes. This method would take over 40 man hours to load a typical blast. In order to speed up the loading of these holes, 2000 lb tote bags were suspended in the air from a 5 ton boom truck. The Anfo can now be poured through a 3" plastic pipe, directly into the blast holes. This method not only reduced the loading time to 16 man hours, it also reduced the chances of injuries to the workers.

CONTACT : Ken Culhane
Blast Hole Technician
Engineering Department
Geco Division
(807) 826-3211 Ext. 209

PORTABLE AIR POWERED ARC WELDER FOR UNDERGROUND 17

This arc welding unit is powered by an air driven motor that can be connected into the mine air lines. This allows the unit to go almost anywhere in the mine without using bulkier or air contaminating power sources. The welding unit is a belt driven Lincoln Welder coupled to a AT-25 Turbinair Motor made by Joy Manufacturing Co.

CONTACT : Bernie Armstrong
Chief, Maintenance Branch
Plant Department
Geco
(807) 826-3211

ZORBAL HOPPER 18

This container is used to store zorbal floor cleaner confined to one area. Each container holds 10 bags of absorbent. Zorbal is dumped into the top of the hopper and collects below in a tray by gravity filling to the top but not overflowing after Zorabal is removed.

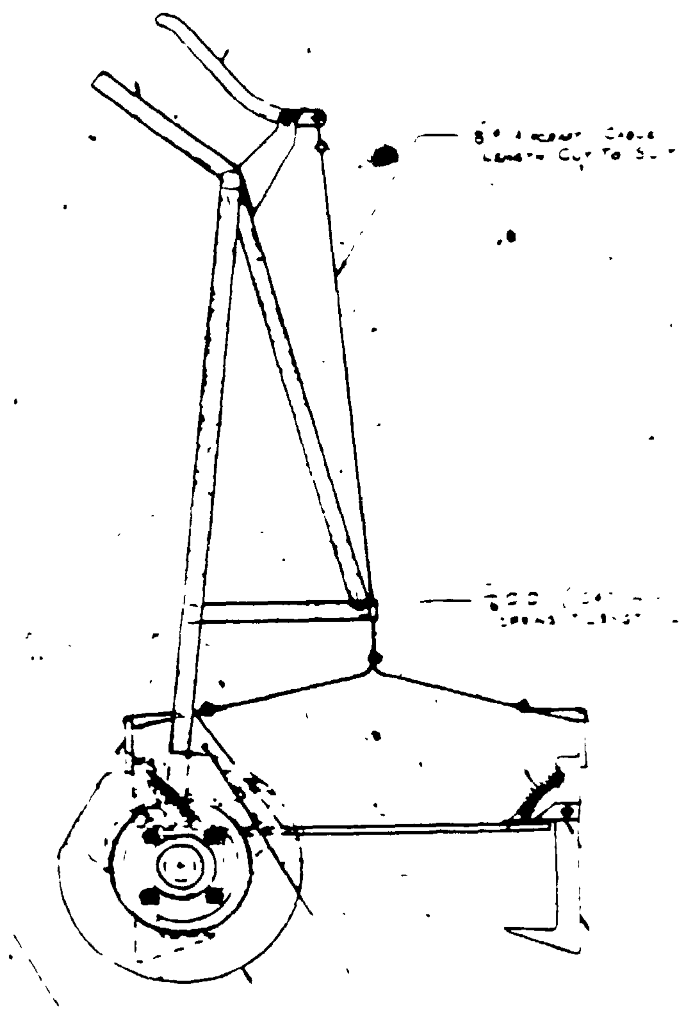
CONTACT : Al Menard
General Foreman
Lyons Lake Mine, Mattabi Lake Division
(807) 934-2291 Ext. 235

GRANBY WHEEL PULLING DOLLEY

19

This device is used to take caste nickle alloy car wheels on and off Granby ore cars. Rather than manhandling the wheels into place, the wheel can be easily positioned by one man.

CONTACT : Bernie Armstrong
Chief, Maintenance Branch.
Plant Department
Geco
(807) 826-3211

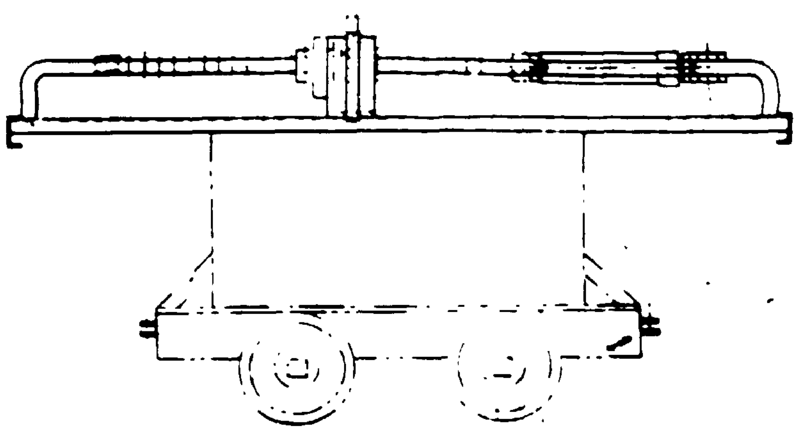


20

CAPPEL DISBANDER

This MTI is used twice a year during maintenance at the mine shaft for X raying the Cappel and shortening the hoist cable. A cart is mounted with a hydraulic jig which grasps the whole cappel securely and strips the rings from the cappel. The cart is positioned next to the shaft so that the cappel can be layed accross the cart with the cable being disconnected from only one end.

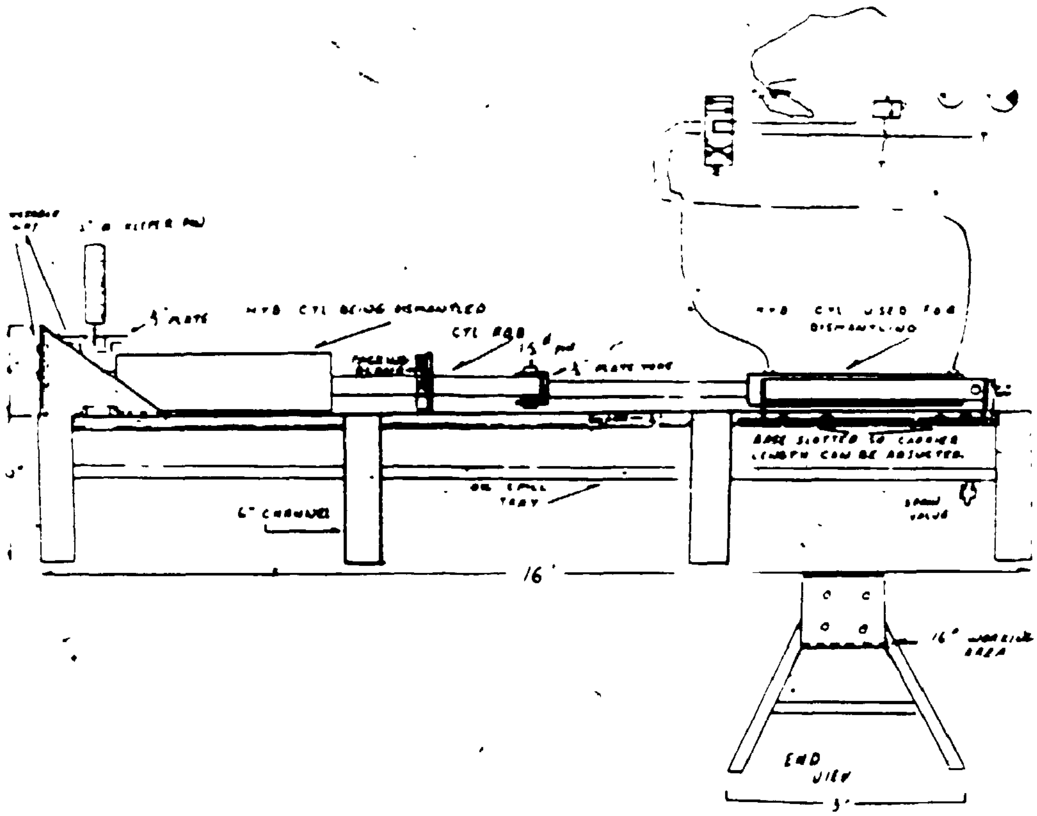
CONTACT : Bernie Armstrong
Chief, Maintenance Branch
Plant Department
Geco
(807) 826-3211



HYDRAULIC CYLINDER JIG

This jig helps in the dismantling of various sized cylinders. Cylinders are harnessed to the jig by a 2" keeper pin and the packing gland is removed manually. A hydraulic cylinder fixed to the jig pulls the rod, piston and packing out of the damaged cylinder. Weight and pull can be adjusted through a slotted fixed base.

CONTACT : Al Menard
General Foreman
Lyons Lake Mine, Mattabi Lake Division
(807) 934-2291 Ext. 235



AUTOMATIC DRY CHEMICAL FIRE ESTINQUISHER RECHARGER AND SERVICE UNIT 22

Prior to this MTI, fire estinquishers were loaded by hand (funnel and scoop) Each estinquisher took about 20 minutes to recharge and clean. The unit fills 10,20 and 30 lbs estinquisher cylinders. It augers chemical from a hopper using a worm gear reduction system powered by a hand held 1/2" drill. When the cylinder is full its weight trips a pressure switch which stops the feed. The feed tube to the cylinder has a sleeve valve to control overspill backing up in the filling chute. The unit has various attachments to assist in servicing by holding the work securely. The device was constructed with $3-400.00 worth of materials and cuts estinquisher filling time by 66%.

CONTACT : Bob Gillis
Carpenter
Plant Department
Mattabi Lake Division
(807) 934-6256 Ext. 274

DRILL PRESS VERSATILLITY VICE 23

A problem was encountered holding work securely on drill press. The MTI is clamped to the base table be one center pin bolt. It can be turned to any angle to accomodate the work. The vice jaws are adjustable to hold work in position. Can be used for both wood and metal. Estimated cost of construction is $100.00.

CONTACT : Bob Gillis
Carpenter
Plant Department
Mattabi Lake Division
(807) 934-6256 Ext. 274

REMOTE OPERATION OF FRONT GATE SECURITY

24

The need for a man on the property security gate was eliminated by giving a remote control unit to the security officer on rounds and to truck drivers hauling from mine to mill. The officer on rounds can act as switch board operator on off-hours from anywhere in the plant. He can also open the gate for people calling from the gate from anywhere in the plant. Has reduced security force by 4 people for an equipment cost of $10,000.00 .

CONTACT : Pierre Beaulieu
Engineer - Mechanical
Plant Department
Mattagami Lake Division
(819) 739-2511 Ext. 129

PRESSURIZED DRIFTS

25

This MTI helps avoid the problems associated with large drops in air pressure underground during drilling operations. A drift was bulkheaded off and air at 90 - 100 PSI pumped in. This cuts down on the number of compressors working at one time. It also keeps the air pressure constant during drilling operations.

CONTACT : Guy Guilleminat
Construction Superintendent
Plant / Engineering
Matagami Lake Division
(819) 739-2511 Ext. 248

PLASTIC BAGS IN SKIP FOR TRANSPORTING SUMP WASTES 26

To keep spillage to a minimum when cleaning the conical sump, the contents of the sump are carried to surface by the skip in plastic bags. The plastic bag lines the skip. On surface the contents are emptied into a waiting truck.

CONTACT : Al Goodier
Mine Department
Mattagami Lake Division
(819) 739-2511

RE-USING DRILL BITS 27

When the life of the down the hole bits are nearly finished the bit is used to drill in the softer waste rock. The bit is serviced before use in the waste. Results in reduced costs per foot drilling in waste.

CONTACT : Al Goodier
Mine Department
Mattagami Lake Division
(819) 739-2511

DRILL PIPE CHANGE 28

The wall of drill pipe was wearing thin, requiring replacement at significant total cost. Instead of buying new pipe, water well pipe of 5/16" thicknebs was substituted. The male and female ends were milled from drill pipe and welded onto the water well pipe. Drill pipe costs $200.00 per length. The new arrangement costs $125.00 per length.

CONTACT : Al Goodier
Mine Department
Mattagami Lake Division
(819) 739-2511

APPENDIX 3

EXAMPLES OF DATA COLLECTION INSTRUMENTS

This appendix contains some of the standardized forms used to guide the researcher and participants in the collection of the data. Examples of the following three instruments are provided

1) MTI INFORMATION FORM : This form was used to document MTIs in Phase 1.

2) PARTICIPANT.INFORMATION FORM : This form was used to collect personal information about each group member in the participating operating units.

3) INSTRUCTION AND EXAMPLE GIVEN GROUPS TO FILL OUT QUESTIONNAIRE: This form was used to collect an operating unit's response to the MTIs described in writing.

1) MTI INFORMATION FORM :

MTI INFORMATION FORM

The following questions are to be answered by each group team concerning the two operating improvements that they consider to be the most successful examples of the two types of MTI. D. Johnston will help finalize a joint team version of this form for each of the two MTI's the team chooses.

MINE OR MILL .... MTI TYPE ....

1) NAME OF MTI: ....

2) DATE OF FIRST USE: ....

3) SOURCE OF MTI (Please list all known personnel involved and in what capacity they contributed.)

....

....

....

....

4) REASON FOR INNOVATION :

....

....

....

....

5) COSTS TO PRODUCE THE FIRST WORKING VERSION OF THE MTI :

....

....

....

....

....

6) EFFECT OF MTI ON PRODUCTION PERRFORMANCE :

Check the following items or comment where appropriate for this MTI.

INPUTS

	DECREASING	INCREASING
1) Labour	......	......
2) Materials	......	......
3) Capital	......	......
4) Energy	......	......

5) Others Effects: ....

....

....

OUTPUTS

	DECREASING	INCREASING
1) Volume	......	......
2) Quality	......	......

3) Others Effects: ....

....

....

QWL

	DECREASING	INCREASING
1) Lost time injuries	......	......
2) Absenteeism	......	......
3) Grievances	......	......
4) Enviromental Factors (eg. noise)	......	......

5) Others Effects: ....

....

....

. ORGANIZATIONAL OR MANAGEMENT CONTROL RELATED EFFECTS
(Comment if appropriate.)

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

7) **EFFECTS OF MTI ON PRODUCTION SYSTEM:** (Comment where appropriate.)

A) Replacement or Displacement of Equipment: . . . .

. . . .

. . . .

B) Replacement or Displacement of People: . . . .

. . . .

. . . .

C) Changes in Areas Linked to Area Directly Affected By the MTI

. . . .

. . . .

8) **RESULTS TO DATE:** (Comment where appropriate.)

A) Has the MTI undergone extensive change since first used ?

. . . .

. . . .

. . . .

8) Have the experienced effects of the MTI differed from expectations?

....

....

....

9) Place a check beside any of the mines and mills listed below that you believe to be using technology similar to this MTI.

MINES AND MILLS

1) Horne Mill	......	9) Matagami Mine	......
2) Chadbourne Mine	......	10) Geco Mill	......
3) Mattabi Mine	......	11) Brunswick Mill	......
4) Remnor Mine	......	12) Mattabi Mill	......
5) Gaspe Mill	......	13) Gallen Mine	......
6) Lyon Lake Mine	......	14) Geco Mine	......
7) Brunswick Mine	......	15) Gaspe Mine	......
8) Matagami Mill	......		

10) Place a check beside any of the mines and mills listed below that could potentially use this MTI.

MINES AND MILLS

1) Horne Mill	......	9) Matagami Mine	......
2) Chadbourne Mine	......	10) Geco Mill	......
3) Mattabi Mine	......	11) Brunswick Mill	......
4) Remnor Mine	......	12) Mattabi Mill	......
5) Gaspe Mill	......	13) Gallen Mine	......
6) Lyon Lake Mine	......	14) Geco Mine	......
7) Brunswick Mine	......	15) Gaspe Mine	......
8) Matagami Mill	......		

2) PARTICIPANT INFORMATION FORM :

The following information will be kept in strictest confidence. The answers to the questions below will only be used in summary statistics to describe the kinds of people that participated in this study. Thank You.

1) Name:..

2) Current Position: ....

3) Birth date: ....

4) Years Employed with Company: ....

5) Work Experience

Before Noranda:

POSITION	TERM OF EMPLOYMENT
....	....
....	....
....	....
....	....

At Noranda:

POSITION	TERM OF EMPLOYMENT	OPERATING UNIT
....	....	....
....	....	....
....	....	....
....	....	....

6) Secondary School Diploma. Please circle,

YES or NO

7) Number of years of Post Secondary School education ....

8) Please list degrees, diplomas or certificates (tickets):

....
....
....
....

9) Have you visited the following Noranda installations in the last 5 years. If so, indicate approximate number of times in the blank provided.

1)	Horne Mill	......	9)	Matagami Mine	......
2)	Chadbourne Mine	......	10)	Geco Mill	......
3)	Mattabi Mine	......	11)	Brunswick Mill	......
4)	Remnor Mine	......	12)	Mattabi Mill	......
5)	Gaspe Mill	......	13)	Gallen Mine	......
6)	Lyon Lake Mine	......	14)	Geco Mine	......
7)	Brunswick Mine	......	15)	Gaspe Mine	......
8)	Matagami Mill	......			

10) Have you served on action groups, management task forces or problem solving groups concerned with operations in your operating unit before ? Please circle,

YES or NO .

If YES, please explain briefly when you served and describe the group objective.

....
....
....
....

11) Do you speak English fluently ? Please circle,

YES or NO .

Do you read and write English fluently ? Please circle,

YES or NO .

3) INSTRUCTION AND EXAMPLE GIVEN GROUPS TO FILL OUT QUESTIONNAIRE :

Please answer for your own department (eg: mine or mill) and only from the section that applies to your department. Please print or type the responses. If you are in doubt about what is a suitable answer to a question for a given NTI, feel free to write a brief note on the questionnaire to qualify your answer. If you need further help or want to discuss one of the NTI you can give D. Johnston a call at one of the numbers supplied in the introduction.

To help in filling out the questionnaire please consult the following example:

1) Is your department (mill, mine or plant) actually using this specific NTI ? (Please circle "NO" or "YES".)

NO YES 1

IF "YES" TO 1) THEN:
Who and Where did the NTI come from ? 2

. . . .

3

IF "NO" TO 1) THEN:
2) Could your department potentially use this specific NTI?
(Please circle "NO" or "YES")

NO YES

4

IF "NO" TO 2) THEN:
Which reason or reasons listed below best describes why your department would not use this NTI ? (Please check the best response(s).)

5 a) Our department is currently using an alternative to this NTI.

6 b) This NTI is not useful given the nature of our production process and equipment.

7 c) Our department is not satisfied that this NTI represents the best alternative for our operation

d) Other. (Please write the reason below.)

. . . .

. . . .

1 "YES" implies that you borrowed this idea from some where else or are the originator of the NTI.

2 Please note name and position of a person or persons if appropriate.

3 "Potentially use", means that you are sufficiently interested in the NTI and convinced of its merit that you would make the effort to phone or write for further information needed to make a decision to adopt the NTI.

4 If you wish to check more than one item, please indicate, if possible which, is the most important reason by numbering the most important, "1",and so on.

5 Your department may have always operating in a way that covered the functions of the NTI.

6 The NTI may not address a problem or opportunity that would arise in your department given your product and process.

7 The NTI may be considered unsafe, inefficient or not worth the effort given the costs and benefits.

APPENDIX 4

NOTE ON STATISTICAL TECHNIQUES USED FOR HYPOTHESIS TESTING

This appendix describes in detail how the collected research data was structured and common statistical tests applied. The following references are suggested for more information on the three tests used in this thesis.

Sidney Siegel, Nonparametric Statistics For The Behavioral Sciences Toronto: McGraw Book Company, 1956.

- For Binomial Test, pp. 36-42
- For Chi Square Test for Two Independent Samples, pp. 63-67
- For Median Test (Modified Chi Square), pp. 111-116

The structuring of the data and the use of the statistical tests will be presented for each hypothesis tested in Chapter 6. Note that an alpha of less than or equal to .05, is the level of significance required for rejection of the null hypothesis and acceptance of the hypothesis as stated below.

Actual Diffusion Hypotheses

Hypothesis 1

A greater number of MTIs will be in use in more than one operating unit. NOT SUPPORTED ($P < .0001$)

NULL HYPOTHESIS:

There is no significant difference between the number of MTIs in use in one operating unit as opposed to more than one. If significant, a greater number of MTIs will be in use in one operating unit.

TEST: .Binomial

DATA: Number of MTIs (N) = 73
Number of MTIs that actually diffused (K) = 7
(In more than one operating unit.)
Proportion of cases expected in one of

the categories (P) = 0.5

DECISION: Null hypothesis is accepted.

COMMENTS: A straightforward use of the binomial test for large samples. Due to the large N, the Z for a normal distribution was used as an approximation.

Hypothesis 2

The more similar the management jurisdiction between an OOU and an NOU the greater the likelihood that an MTI will be actually used by the NOU.

NOT SUPPORTED (P =.1094)

NULL HYPOTHESIS:

There will be no difference in the number of MTIs actually used by NOUs from OOUs that share management jurisdiction versus having different jurisdictions.

TEST: Binomial

DATA: Same Group = 2 Different Group = 6
Number of observations of actual diffusion (N) = 8
Number of observations in smaller frequency (K) = 2
Proportion of cases expected in one of the categories (P) = 0.5

DECISION: The Null Hypothesis is accepted.

Hypothesis 3

The greater the geographic proximity between an OOU and an NOU the greater the likelihood that an MTI will be actually be used by the NOU.

NOT SUPPORTED (P =.2188)

NULL HYPOTHESIS:

There will be no difference in the number of MTIs actually used by NOUs and OOUs that are in close geographic proximity versus greater geographic proximity.

TEST: Binomial

DATA: Close = 3 Distant = 5
Number of observations of actual diffusion (N) = 8
Number of observations in smaller frequency (K) = 3
Proportion of cases expected in one of the categories (P) = 0.5

DECISION: The Null Hypothesis is accepted.

Hypothesis 4

The more similar the processes between an OOU and an NOU the greater the likelihood that an MTI will be actually used by the NOU. As measured by: NOT SUPPORTED

Output Volume	(P =.2188)
Manpower	(P =.2734)
Labour Productivity	(P =.1094)
Mineral Reserves	(P =.3125)
Age of Operating Unit	(P =.2188)

NULL HYPOTHESIS:

There will be no difference between the number of MTIs used by NOUs from OOUs that have high similarity versus low similarity.

TEST: Binomial

DATA: OUTPUT VOLUME -
Low = 5 High = 3
Number of observations of actual diffusion (N) = 8
Number of observations in smaller frequency (K) = 3
Proportion of cases expected in one of the categories (P) = 0.5

MANPOWER -
Low = 4 High = 4
Number of observations of actual diffusion (N) = 8
Number of observations in smaller frequency (K) = 4
Proportion of cases expected in one of the categories (P) = 0.5

LABOUR PRODUCTIVITY -

Low = 6 High = 2
Number of observations of actual diffusion (N) = 8
Number of observations in smaller
frequency (K) = 2
Proportion of cases expected in one of
the categories (P) = 0.5

MINERAL RESERVES -
Low = 3 High = 2 Missing Data = 3
Number of observations of actual diffusion (N) = 5
Number of observations in smaller
frequency (K) = 2
Proportion of cases expected in one of
the categories (P) = 0.5

AGE OF OPERATING UNIT -
Low = 3 High = 5
Number of observations of actual diffusion (N) = 8
Number of observations in smaller
frequency (K) = 3
Proportion of cases expected in one of
the categories (P) = 0.5

DECISION: For all variables the Null Hypothesis was accepted.

COMMENTS: The smaller N for Mineral Reserves is the result of information not being available for three of the observations. The same median values used in Hypothesis 9 were used to place observations in either low or high categories.

<u>Hypothesis 5:</u>

An MTI will be adopted by an NOU during a limited time period after being innovated by the OOU or it will not be adopted at all. NOT SUPPORTED (P =.2188)

NULL HYPOTHESIS:

There will be no difference between the number of MTIs adopted by an NOU soon after being innovated by the OOU versus later.

TEST: Binomial

DATA: Younger = 3 Older = 5
Median Value for Classification = 2 years
Number of observations of actual diffusion (N) = 8

Number of observations in smaller frequency (K) = 3
Proportion of cases expected in one of the categories (P) = 0.5

DECISION: The null hypothesis is accepted.

Hypothesis 6

PMTIs will be actually used by a greater number of NOUs than will QMTIs. NOT SUPPORTED (P =.3088)

NULL HYPOTHESIS:

There will be no difference in the proportion of PMTIs versus QMTIs of potential use to NOUs.

TEST: Binomial

DATA: PMTIs = 5 QMTIs = 2
Number of observations of actual diffusion (N) = 7
Number of observations in smaller frequency (K) = 2
Proportion of cases expected in one of the categories (P) = 0.33

DECISION: The Null Hypothesis is accepted.

COMMENTS: The use of p=.33 compensates for the greater number of PMTIs in the sample as opposed to QMTIs.

Potential Diffusion Hypotheses

Hypothesis 7

The more similar the management jurisdiction between an OOU and an NOU the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU. NOT SUPPORTED (P = 1.0)

NULL HYPOTHESIS:

There will be no difference in the number of MTIs that could potentially be used by NOUs from OOUs that share similar management jurisdiction versus different jurisdiction.

TEST: Chi Square for Two Independent Samples

DATA:

COUNT		No Use 1	Pot. Use 2	ROW TOTAL
Same	1	49	24	73 19.3
Different	2	204	101	305 80.7
	COLUMN TOTAL	253 66.9	125 33.1	378 100.0

CHI-SQUARE	D.F.	SIGNIFICANCE
0.0	1	1.0000

DECISION: The Null Hypothesis is accepted.

Hypothesis 8

The greater the geographic proximity between an OOU and an NOU the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU.

NOT SUPPORTED (P =.2749)

NULL HYPOTHESIS:

There will be no difference in the number of MTIs that could potentially be used by NOUs from OOUs that have high geographic proximity versus low geographic proximity.

TEST: Chi Square for Two Independent Samples

DATA:

	COUNT	No Use 1	Pot. Use 2	ROW TOTAL
Same	1	31	23	54 14.3
Adjacent	2	165	76	241 63.8
Distant	3	57	26	83 22.0
	COLUMN TOTAL	253 66.9	125 33.1	378 100.0

CHI-SQUARE	D.F.	SIGNIFICANCE
2.58299	2	0.2749

DECISION: The Null Hypothesis is accepted.

COMMENTS: When PMTIs described in writing from mines were tested separately the data looked as follows:

COUNT	Not Use 1	Pot. Use 2	ROW TOTAL
1 Same	8	12	20 16.7
2 Adjacent	59	23	82 68.3
3 Distant	16	2	18 15.0
COLUMN TOTAL	83 69.2	37 30.8	120 100.0

CHI-SQUARE	D.F.	SIGNIFICANCE
11.55895	2	0.0031

Hypothesis 9

The more similar the processes between an OOU and an NOU the greater the likelihood that an MTI will be perceived to be potentially useful by both the OOU and NOU. As measured by: NOT SUPPORTED

Output Volume	(P =.658)
Manpower	(P =.382)
Labour Productivity	(P =.719)
Mineral Reserves	(P =.910)
Age of Operating Unit	(P =.535)

NULL HYPOTHESIS:

There will be no difference in the number of MTIs that could be potentially used by NOUs from OOUs that have high similarity versus low similarity in processes.

TEST: Median Test (Modified Chi Square)

DATA: Note that in the testing of this hypothesis, it is the difference between the NOU and OOU in each observation which is being categorized. "Low" on the vertical axis refers to a low difference and likewise for "high".

OUTPUT VOLUME -

COUNT / EXP VAL	No Use 1	Pot. Use 2	ROW TOTAL
low 1	130 132.5	68 65.5	198 52.4%
high 2	123 120.5	57 59.5	180 47.6%
COLUMN TOTAL	253 66.9%	125 33.1%	378 100.0%

MEDIAN TEST	D.F.	SIGNIFICANCE	MEDIAN VALUE
0.19627	1	0.6578	837,600 tons

MANPOWER -

COUNT / EXP VAL	No Use 1	Pot. Use 2	ROW TOTAL
low 1	131 126.5	58 62.5	189 50.0%
high 2	122 126.5	67 62.5	189 50.0%
COLUMN TOTAL	253 66.9%	125 33.1%	378 100.0%

MEDIAN TEST	D.F.	SIGNIFICANCE	MEDIAN VALUE
0.76496	1	0.3818	91 employees

LABOUR PRODUCTIVITY -

COUNT / EXP VAL	No Use 1	Pot. Use 2	ROW TOTAL
1 low	119 / 121.1	62 / 59.9	181 / 47.9%
2 high	134 / 131.9	63 / 65.1	197 / 52.1%
COLUMN TOTAL	253 / 66.9%	125 / 33.1%	378 / 100.0%

MEDIAN TEST	D.F.	SIGNIFICANCE	MEDIAN VALUE
0.12969	1	0.7188	2,137 tons per man

MINERAL RESERVES --

COUNT / EXP VAL	No Use 1	Pot. Use 2	ROW TOTAL
1 low	88 / 87.0	42 / 43.0	130 / 34.4%
2 high	165 / 166.0	83 / 82.0	248 / 65.6%
COLUMN TOTAL	253 / 66.9%	125 / 33.1%	378 / 100.0%

MEDIAN TEST	D.F.	SIGNIFICANCE	MEDIAN VALUE
0.01269	1	0.9103	18 years

AGE OF OPERATING UNIT -

	COUNT / EXP VAL	No Use 1	Pot. Use 2	ROW TOTAL
low	1	150	79	229
		153.3	75.7	60.6%
high	2	103	46	149
		99.7	49.3	39.4%
	COLUMN TOTAL	253	125	378
		66.9%	33.1%	100.0%

MEDIAN TEST	D.F.	SIGNIFICANCE	MEDIAN VALUE
0.38474	1	0.5351	17 years

DECISION: The Null Hypothesis is accepted for all variables.

COMMENTS: In Chapter 6, a significant result was found for Output Volume when only the observations for MTIs described in writting were tested. The data were organized as follows:

OUTPUT VOLUME (WRITTEN MTIs) -

VDIFF	COUNT / EXP VAL	ADOPT: No Use 1	Pot. Use 2	ROW TOTAL
low	1	60 / 67.8	41 / 33.2	101 / 47.4%
high	2	83 / 75.2	29 / 36.8	112 / 52.6%
	COLUMN TOTAL	143 / 67.1%	70 / 32.9%	213 / 100.0%

MEDIAN TEST	D.F.	SIGNIFICANCE	MEDIAN VALUE
4.55727	1	0.0328	837,000 tons

Hypothesis 10

PMTIs will be perceived as potentially useful to a greater number of NOUs than will QMTIs.

NOT SUPPORTED (P =.787)

NULL HYPOTHESIS:

There will be no difference in the proportion of PMTIs versus QMTIs of potential use to NOUs.

TEST: Chi Square for Two Independent Samples

DATA:

TYPE	COUNT / EXP VAL	ADOPT: No Use 1	Pot. Use 2	ROW TOTAL
PMTIs	1	169 167.3	81 82.7	250 66.1%
QMTIs	2	84 85.7	44 42.3	128 33.9%
	COLUMN TOTAL	253 66.9%	125 33.1%	378 100.0%

CHI-SQUARE	D.F.	SIGNIFICANCE
0.07330	1	0.7866

DECISION: The Null Hypothesis is accepted.

APPENDIX 5

NOTE ON ACCOUNTING FOR THE COSTS AND BENEFITS OF MTIs AND THEIR DIFFUSION

Actual Net Savings

Actual net dollar savings were experienced by the participating operating units in the research as a result of using the 73 MTIs sampled. Fifty of the MTIs had sufficiently accurate and complete cost and matching savings data to be used for these calculation. In order for an MTI to be used in the following calculations of actual and potential net savings, there had to be both cost and corresponding savings information. Some MTIs, mainly QMTIs, were described by their respective OOUs as not having any quantifiable dollar savings. For these MTIs, the "net benefits" associated with their use were often intangibles relating to improved QWL. Since 50 of the 73 MTIs used in the research were included in these calculations, the resulting totals are best viewed as estimates of net savings associated only with the MTIs and operating units used in this research. Table A5.1 contains an identification number (MNDX), the name and source operating unit for the MTIs used in the calculations. Table A5.2 contains the results of the following calculations:

1) Calculation of Annual Costs. Column (1) of Table A5.2 lists the annual costs for each of the MTIs. The mean and median are noted at the bottom of the column.

2) Calculation of the Length of Time Costs were Experienced. Column (2) of Table A5.2 shows the number of years that the costs for each MTI in Column (1) were experienced. Note that many of the MTIs had one-time costs. The costs for these MTIs were not amortized over their productive lives but were written off in the year they were incurred.

3) Calculation of Lifetime Costs. Column (3) contains the product of columns (1) and (2), representing the savings experienced over the life of an MTI as of October 1 1985.

4) Calculation of Annual Savings. Column (4) contains the annual savings associated with an MTI. Note that the revenues produced by the sale of an MTI to other operating units or companies were included in the savings experienced by the OOU. The mean and median are calculated at the bottom of Column (4).

5) Calculation of the Length of Time Savings Were Experienced. Column (5) records the number of years that the annual savings from an MTI were experienced, as of October 1 1985.

6) Calculation of Lifetime Savings. Column (6) contains the product of Columns (4) and (5) representing the savings experienced over the life of the MTI, as of October 1 1985.

7) Calculation of Lifetime Net Savings. Column (7) contains the difference between Column (6) and (3) representing the net savings experienced over the life of the MTI, as of October 1 1985.

Potential Net Savings

The calculation of potential net savings for the 73 MTIs from the 13 operating units involved in this research, is based on two major assumptions. First, all Non-originating Operating Units (NOUs) that indicated that they could potentially use an MTI actually follow through with adoption of that MTI. Second, the economies of the use of an MTI by an NOU will be similar to those of the OOU. The following calculations estimate the potential total net savings of the MTIs (the 50 with cost and matching savings data) to the whole corporation, as of October 1 1985, if the MTIs had been diffused imediately after their first use by the OOU to all NOU's that had indicated potential use.

Thirty of the 50 MTIs with cost and savings data experienced net savings greater than 0. Column (1) in Table A5.3 contains the number of operating units that actually used an MTI. The number of operating units which indicated the potential use of an MTI is recorded in Column(2). Columns (1) and (2) are added together and multiplied by Column (7) in Table A5.2 to derive Column (3), the total net savings that could have been experienced across the corporation, if the potentially useful MTIs had actually been diffused. Total net savings for all the MTIs were estimated at $11.6 million, as of October 1 1985. Note the following limitations on the estimate. First, some of the 73 MTIs did not have accurate cost and savings data and thus could not be included in th calculations, even though they may have achieved some net savings. Second, diffusion between OOU and NOU is assumed to be instantaneous in these calculations; therefore net savings would be experienced by the adopting NOU soon after the MTI is innovated at an OOU. Finally, these estimates may not be generalizable to any sampling of 73 MTIs from 13 operating units.

TABLE A5.1 - Index of MTIs Used In Research

MNDX	MTI Title	Source
VIDEO TAPED MTIs		
1	Copper Sulfate Mixing System	Mattabi Mill
2	Dust Collector Over Slot Feeder	Mattabi Mill
3	Bulk Cyanide Handling and Mixing System	Geco Mill
4	Continuous Polymer Feeding System	Geco Mill
5	Remote Graphic X-Ray Analysis	Horne Mill
6	Lubricated Lantern Ring in Cyclone Chute	Horne Mill
7	Slurry Screen for Pressure Filter Feed	Matagami Mill
8	Sulfur Dioxide Conditioner	Matagami Mill
9	NaHs Feeder Modification	Gaspe Mill
10	Safety Breaking Device for Large Trucks	Gaspe Mill
11	Earthwork Supports for Tailings Pipes	Brunswick Mill
12	Radio Headsets for Crane Operations	Brunswick Mill
13	Cappel Remover for Skip	Mattabi Mine
14	Rock Breaker Setup Modifications	Mattabi Mine
15	Hot Tank for Cleaning Mechanical Parts	Lyons Lake Mine
16	Mobile Waste Oil Tank	Lyons Lake Mine
17	Concrete Transportation Car	Geco Mine
18	Pipe Handling Device	Geco Mine
19	Battery Charger for Remote Scoop Tram Transmitters	Horne Mines
20	Brake Compressor Remount on ST2B	Horne Mines
21	Computerization of Clerical Duties	Horne Mines
22	Modification of Seating on Scoop Tram	Horne Mines
23	Screening of Ore to Avoid Bin Freezing	Horne Mines

TABLE A5.1 (cont)

MNDX	MTI Title	Source
24	Smoke Detection on Ventillation for Mine	Horne Mines
25	BBC - 120 Drill Modification	Matagami Mine
26	Production Blast Hole Casing Colars	Matagami Mine
27	Drill Hole Dewatering	Gaspe Mine
28	Man / Equipment Basket for Scoop Tram	Gaspe Mine
29	Friction Washer for Screening Support	Brunswick Mine
30	Noise Suppression Package on Scoop Tram	Brunswick Mine

MTIs DESCRIBED IN WRITING

MNDX	MTI Title	Source
31	Dust Suppression System on Lead Dryers	Brunswick Mill
32	Density Control of Settling Thickeners	Brunswick Mill
33	Linatex Pump Impeller Modifications	Brunswick Mill
34	Positive Locking Plugs	Brunswick Mill
35	Low Friction Cassettes on Conveyor Belt	Brunswick Mill
36	Bipod for Mill Liner Installation	Geco Mill
37	Hot Splice Vulcanizing for Conveyor System	Brunswick Mill
38	Floc Settling Rate Monitor	Geco Mill
39	Grooving of Polyethylene Pipe with Router	Geco Mill
40	Lime Mixing System	Geco Mill
41	Air Nozzles for Aerators	Geco Mill
42	Rubber Plugs to Seal Bolt Holes in Ball Mill Liner	Horne Mill
43	Tailing Line Supports Made from Pallets	Horne Mill
44	Improvements in Ore Bin Flow by use of Calcium Solution	Horne Mill
45	Lime Degritting	Matagami Mill
46	Underground Emergency Vehicle	Brunswick Mine
47	Cablebolt Feeding Machine	Brunswick Mine

TABLE A5.1 (cont)

MNDX	MTI Title	Source
48	Cablebolt Cutting Device (DETA - CAB)	Brunswick Mine
49	Rock Bolt Dollie	Brunswick Mine
50	Replacement of Mechanical with Hydrostatic Transmissions	Brunswick Mine
51	Particulate Filter for Diesel Emissions	Brunswick Mine
52	Replacement of Screw Feed to Chain Feed on Drill Jumbo	Brunswick Mine
53	Safety Limit Switch on Truck Box Controls	Gaspe Mine
54	Pressurized System for Cone Operations	Gaspe Mine
55	Electronic Fan Reversing for Ventillation and Cooling	Gaspe Mine
56	Underground Fueling Station	Gaspe Mine
57	Dewatering Boreholes in Mine	Geco Mine
58	Magic Hammer	Geco Mine
59	Square Drop Raise Set-up	Geco Mine
60	Drop Raise-drilling with I.T.H. Drill	Geco Mine
61	Anfo Tote Bags in Quarry	Geco Mine
62	Portable Air Powered Arc Welder for Underground	Geco Mine
63	Zorbal Hopper	Lyons Lake Mine
64	Granby Wheel Pulling Dolley	Geco Mine
65	Cappel Disbander	Geco Mine
66	Hydraulic Cylinder Jig	Lyons Lake Mine
67	Automatic Dry Chemical Fire Estingquisher Recharger and Service unit	Mattabi Mine
68	Drill Press Versatillity Vice	Mattabi Mine
69	Remote Operation of Front Gate Security	Matagami Mine
70	Pressurized Drifts	Matagami Mine
71	Plastic Bags in Skip for Transporting Sump Waste	Matagami Mine
72	Re-using Drill Bits	Matagami Mine
73	Drill Pipe Change	Matagami Mine

TABLE A5.2 - Calculation of Actual Net Savings

MNDX	COST (1)	T (2)	LCOST (3)	SAVING (4)	T (5)	LSAVING (6)	NET LSAVING (7)
1	20000	1	20000	32500	.5	16250	0
2	5000	1	5000	0	-	0	0
3	8000	1	8000	0	-	0	0
4	2620	1	2620	20000	1	20000	20000
6	2000	1	2000	42500	3	127500	125500
7	100	1	100	9000	1.5	13500	13400
8	6295	1	6295	0	-	0	0
11	1314	1.5	1971	10200	1.5	15300	13329
13	100	1	100	0	-	0	0
15	1200	1	1200	70000	1	70000	78800
16	369	1	369	0	-	0	0
17	3600	1	3600	70000	4	280000	276400
21	1300	1	1300	35000	0.5	17500	16200
22	180	1	0	0	-	0	0
23	5000	1	0	5000	1	5000	0
24.	100	0	0	0	-	0	0
25	3100	1.5	4650	40800	1.5	61200	56550
27	14000	1	14000	500000	1	500000	486000
28	5000	1	5000	0	-	0	0
29	1200	1	1200	500400	3	1501200	1500000
30	4200	1	4200	0	-	0	0
33	2700	1.5	4050	26000	1.5	39000	34950
35	8000	1.5	8000	36000	1.5	54000	46000
36	100	*	100	0	-	0	0
38	700	1	700	10000	2	20000	19300
40	600	1.5	900	1600	1.5	2400	1400

TABLE A5.2 - (continued)

MNDX	COST (1)	T (2)	LCOST (3)	SAVING (4)	T (5)	LSAVING (6)	NET LSAVING (7)
41	1000	3.5	3500	5000	3.5	17500	14000
42	*	*	*	*	*	*	1200
43	*	*	*	*	*	*	40000
45	1500	1	1500	2300	3.0	6900	5400
47	7000	1	7000	70000	3.5	245000	238000
48	0	*	0	0	*	0	0
49	10	1	10	6200	1	6200	6190
50	28000	1	28000	47000	1	47000	19000
51	0	*	0	0	*	0	0
52	27000	1	27000	*	*	*	873000
54	C	*	0	0	*	0	0
56	1000	1	1000	50000	*	50000	49000
57	37000	1	37000	18500	2	37000	0
58	300	1	300	18000	2	90000	89700
59	100	1	100	10000	3	30000	29900
61	0	*	0	8400	1.5	12600	12600
66	1380	1	1380	14352	1	14352	14532
69	10000	1	10000	150000	1	150000	140000
72	0	1	0	1380	1	1380	1380
MEAN	4908.6			43098.0			93816.0
MEDIAN	1314.0			9500.0			33261.0

TOTAL NET SAVINGS = $ 4,221,728
(Sum of Column 7)

NOTES: All numbers are in Canadian dollars.
Symbols in this table are interpreted aa follows:
* = missing exact values
\- = not relevant

TABLE A5.3 - Calculation of Potential Net Savings

MNDX	Actual Users (1)	Potential Users (2)	Net Potential Savings (3)
4	1	2	40,000
6	0	4	502,000
7	0	0	0
11	0	0	0
15	0	4	315,200
17	0	2	582,800
21	0	2	32,400
25	0	1	56,550
27	0	1	486,000
29	0	5	7,500,000
33	0	0	0
35	0	1	46,000
38	0	2	38,600
40	0	1	1,400
41	0	0	0
42	0	1	1,200
43	0	1	40,000
45	1	1	5,400
47	1	2	476,000
49	0	2	12,380
50	0	0	0
52	0	1	873,000
56	0	0	0
58	0	3	269,100
59	0	2	58,800
61	1	1	12,600
66	0	0	0
69	0	2	280,000
72	0	0	0

Total Potential Net Savings After Diffusion: $11,600,430

NOTE: All numbers in Column 3 are Canadian dollars

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RUBBER PLUGS TO SEAL BOLT HOLES INSIDE BALL MILL LINER

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A problem was experienced with the primary mill when lifters were being changed at the discharge end. Fine slag would get behind these bars and into the bolt holes. This fine slag would become as hard as cement, which would make it extremely difficult to remove the worn bars when replacement was necessary. The solution found was to install a soft rubber ring around the bolts and under the lifter bars. This MTI saves $ $1200.00 a year and has also reduced mill downtime and accident risks.

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TAILING LINE SUPPORTS MADE FROM PALLETS

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Rather than building a support trestle for tailings pipe from new wood, old or surplus pallets were used to support the tailings lines. In the past, the pallets would have been destroyed. This MTI reduces the cost of the materials used and speeds up installation time.

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